İSTANBUL TECHNICAL UNIVERSITY ★ INSTITUTE OF SCIENCE AND TECHNOLOGY

COMPARATIVE ANALYSIS OF DYNAMIC AND SIMPLIFIED ENERGY PERFORMANCE METHODS FOR HOSPITAL BUILDINGS

M.Sc. Thesis by
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Department : **Architecture**

Programme : **Environmental Control and Building Technologies**

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DİNAMİK VE BASİTLEŞTİRİLMİŞ ENERJİ PERFORMANS YÖNTEMLERİNİN HASTANE BİNALARI İÇİN KARŞILAŞTIRMALI ANALİZİ

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FOREWORD

I would like to express my deep appreciation and thanks for my advisor Prof. Dr. A. Zerrin Yılmaz for her support during my master education and this study.

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June 2011 Gözde GALİ

(Architect)

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ABBREVIATIONS

IVF	**:** In Vitro Fertilization
HEA	**:** Hospital Energy Alliance
EPBD	**:** Energy Performance of Buildings Directive
BEP-tr	**:** Building Energy Performance Turkey
DOE	**:** Department of Energy USA
EU	**:** European Union
R-C	**:** Resistance-Capacitance
HB	**:** Heat Balance
RTS	**:** Radiant Time Series
$\mathbf{Q_{ht}}$	**:** Total heat gain/loss in a zone
$\mathbf{Q_{tr}}$	**:** Heat gain/loss through transmission
$\mathbf{Q_{ve}}$	**:** Heat gain/loss through ventilation
$\mathbf{Q_{sol}}$	: Solar heat gain
$\mathbf{Q_{ig}}$	**:** Internal heat gains
$\mathbf{\Phi_{m}}$	**:** Heat flow from internal and solar heat sources
$\mathbf{A_{m}}$	**:** Useful surface area
$\mathbf{A_{tot}}$	**:** Area of all surfaces facing the room
$\mathbf{\Phi_{int}}$	: Internal heat gains
$\mathbf{\Phi_{sol}}$	**:** Solar heat gain

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COMPARATIVE ANALYSIS OF DYNAMIC AND SIMPLIFIED ENERGY PERFORMANCE METHODS FOR HOSPITAL BUILDINGS

SUMMARY

Energy certification is an important subject and the adoption of a suitable energy performance calculation methodology is fundamental to determine the building energy demand. The adoption of a calculation method is not a problem for residential buildings; however, it is crucial for complex buildings. The ‘Simple Hourly Method’ that adopted in Turkey for energy performance calculations of the buildings works for residential, educational, and office buildings. When calculation algorithm is applied to complex buildings such as hotels, healthcare buildings, shopping malls and commercial buildings, the energy assessor has to face a number of assumptions due to the complexity of the building typology which have a significant effect on annual heating and cooling demand results. This study focuses on the energy performance calculations of hospital buildings by analyzing ‘Simple Hourly Method’ and ‘Detailed Dynamic Method’ since the algorithm of detailed dynamic method is appropriate to assess the energy performances of hospital buildings. To this aim, a road map is followed. First of all, the Building Energy Performance Turkey (BEP-tr) representative of simple hourly method and internationally recognized energy performance simulation tool Energy Plus representative of detailed dynamic method are analyzed.

After analyzing the methods separately, to understand the differences between the methods both of them are compared respectively for the boundary condition data and calculation methodologies by using an example benchmark hospital project from Energy Plus database. After obtaining the reason of the differences, an existed IVF Center project is analyzed by using different standards to show the effect of the complete boundary condition data usage and how to obtain the boundary condition data for hospital buildings.

All of these tests show the shortcomings of BEP-tr in compare to Energy Plus and provide a new perspective to improve the simplified method to be able to assess energy performances of hospital buildings.

At last, with an energy manager from the partner university Politecnico di Torino for this study, CTO Torino is examined to evaluate the current condition of hospitals and then, the standard boundary condition data for hospital buildings through the IVF Center project is compared to the monitored data through CTO Torino to be able to show how variability in input data can effect the heating and cooling demand results and how these data can differ from one hospital to another.

In conclusion, two ways are recommended to assess the building energy performance of hospitals.

DİNAMİK VE BASİTLEŞTİRİLMİŞ ENERJİ PERFORMANS YÖNTEMLERİNİN HASTANE BİNALARI İÇİN KARŞILAŞTIRMALI ANALİZİ

ÖZET

Enerji sertifikasyonu günümüzde önemli bir konudur ve binaların enerji ihtiyaçlarını belirleyebilmek için uygun enerji performansı hesaplama yöneteminin belirlenmesi gerekmektedir. Bir hesaplama yönteminin konut binalarına uygun seçilmesi problem teşkil etmemektedir, ancak kompleks binalar için yöntem seçimi önemlidir. Türkiye tarafından ulusal bina enerji performansı hesaplama yöntemi için baz alınan 'Basit Saatlik Metod' konut, eğitim, ve ofis binaları için sorun teşkil etmemektedir. Ancak hesaplama algortiması oteller, sağlık binaları, alışveriş merkezleri ve ticari binalar gibi kompleks binalara uygulandığında enerji sertifikatörleri bina tipolojisinin komplekslik oranına göre bir çok varsayımla karşı karşıya kalmaktadırlar ve bu varsayımların binanın yıllık ısıtma ve soğutma ihtiyaçları sonuçlarında büyük etkisi vardır. Bu çalışma 'Basit Saatlik Metod' ve 'Detaylı Dinamik Metod' yöntemlerini karşılaştırarak hastane binalarının enerji performansı hesaplamaları üzerinedir. Detaylı dinamik metod, genel anlamda hastane binalarının enerji performans değerlendirmeleri açısından uygun olduğu için bu karşılaştırmaya gidilmiştir. Bu amaçla izlenen yolda ilk olarak basit saatlik metodu temsilen Bina Enerji Performansı Türkiye (BEP-tr) ve detaylı dinamik metodu temsilen uluslararası anlamda bilinen Energy Plus analiz edilmiştir.

Metodları ayrı ayrı analiz ettikten sonra, yöntemler arasındaki farkı anlamak için Energy Plus veritabanından örnek bir hastane projesi aracılığı ile her iki metodun sırasıyla sınır koşulları ve hesaplama yöntemleri karşılaştırılmıştır. Metodlar arasındaki farkların nedenleri anlaşıldıktan sonra, mevcut bir Tüp Bebek ve Kadın Doğum Merkezi projesi farklı standartlardan yararlanılarak tamamlanmış sınır koşullarının etkisini ve bir hastane binası için sınır koşullarının nasıl elde edilebileceğini göstermek açısından incelenmiştir. Tüm bu testler Energy Plus'a kıyasla BEP-tr'nin eksiklerini göstermiş ve basitleştirilmiş metodu hastane binalarının da enerji performanslarını hesaplayabilecek biçimde geliştirmek üzere yeni bir bakış açısı sağlamıştır.

Son olarak, bu çalışmada ortak üniversite olarak yardım eden Politecnico di Torino'da doktora yapmakta olan bir enerji yöneticisi ile CTO Torino, hastane binalarının günümüzdeki durumlarını göstermek üzere test edilmiştir. Bunun yanında da, hastaneler için standard sınır koşulu verileri Tüp Bebek ve Kadın Doğum Merkezi projesi yolu ile CTO Torino çalışmasında ölçümler yolu ile elde edilen sınır koşulu verileri ile karşılaştırılarak, veri girişlerindeki farklılıkların ısıtma ve soğutma ihtiyaçlarını nasıl etkilediği ve verilerin bir hastaneden bir diğer hastaneye nasıl farklılaşabileceği gösterilmiştir. Sonuç olarak, hastane binalarının enerji performanslarının değerlendirilebilmesi için iki yol önerilmiştir.

1. INTRODUCTION

Commercial building sector, which includes hotels, hospitals, shopping malls, etc. has been growing at a fast pace. As per Central Electricity Authority, the growth of energy consumption in the sector has been highest at over 14% [1].

Hospitals are among the most energy intensive of all commercial buildings in all countries and the healthcare industry as a whole represents a substantial fraction of total US commercial building energy use. While healthcare facilities have many special characteristics that lead to higher energy consumption, there is broad recognition among knowledge designers and operators that energy use can be reduced substantially with net economic benefit to the industry [2].

In US, healthcare facilities consume four percent of the total energy consumed including all energy used by industry, transportation, and buildings. One average-sized US hospital produces approximately 18,000 tons of carbon dioxide annually. In addition, hospitals use 8.82*1017 joules energy annually and have more than 2.5 times the energy intensity and carbon dioxide emissions of commercial office buildings, producing more than 146.5 kilograms of CO_2 emissions per square meter [3].

Nowadays Hospital Management is an important subject in US and Europe. According to the Hospital Energy Alliance (HEA), reducing the energy use of healthcare facilities offers many key benefits:

- Improved profitability
- Reduced impact on volatile energy costs
- Lower operations and maintanence costs
- Improved environmental performance
- Reduced carbon footprint
- Healthier healing and work environment and communities

1.1 Purpose of the Thesis

Energy efficiency is the target to obtain less toxic gas emissions and, also to have lower energy consumption levels and better energy performance levels in building sector. To this aim, the building energy certification is one of the most important topics faced in the last years.

The energy-consuming rate of buildings can be calculated by simulation methods with appropriate algorithms. A lot of improved energy performance simulation methods and calculation methodologies are available in each country for building sector. Some of these methods are on national base, and the others are on international base. National methods are developed according to the Energy Performance of Buildings Directive (EPBD) in Europe. The EPBD Platform is another initiative of the European Commission. Since, reducing energy consumption and eliminating wastage are among the main goals of the European Union, implementation of EPBD requires all EU countries to enhance their building regulations and to introduce energy certification schemes for buildings [4]. The objectives of EPBD are [5];

- Assist with creation and adoption of national laws and regulations for certification, inspection and testing markets
- Create favourable conditions for common solutions and standardisation
- Support the follow up of legislative implementation
- Encourage sharing of experience, good practice and networking in the field

Turkey is consistent with the same objectives by following EPBD to develop a national regulation for building energy performance evaluations.

The improvement process of the methods is an on-going project, however there are a lot of energy performance simulation methods on national base which are improved enough for residential buildings in each country. In the terms of energy certification, there are buildings can be classified as residential buildings and non-residential buildings. Energy performance assessments of residential buildings are not a very problematic case and as discussed in Figure 1.1, the residential buildings are not alone in energy consumption, it is very important to deal with non-residential buildings.

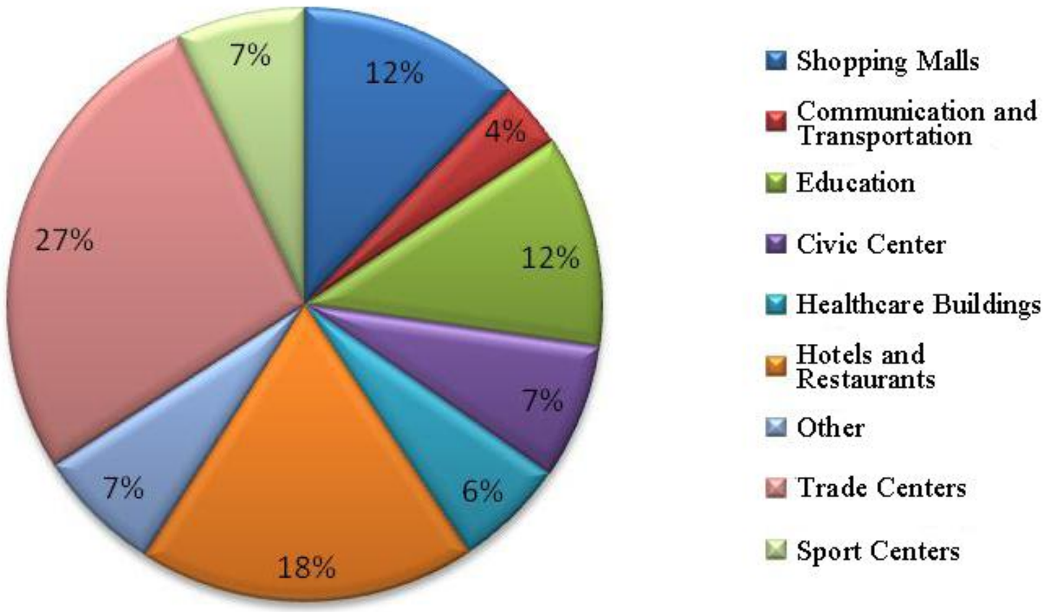


Figure 1.1 : England, the sectorial energy consumption rate, 2006 [6].

The algorithm of national energy performance calculation method adopted in Turkey (Building Energy Performance Turkey, BEP-tr) has been developed for all kind of buildings both residential and non-residential as Turkish Ministry of Public Works and Settlement predicts to assess their energy/emission class through a simplified methodology. However, for now it is better to use this method for residential, educational, and office buildings.

Nowadays, the most complicated problem is the energy performance calculations and design of complex buildings that expresses non-residential buildings. These include hotels, healthcare buildings, shopping malls and commercial buildings.

The healthcare sector represents a great opportunity and a great challenge for high-tech energy efficiency [7]. Hospitals are among the most energy intensive of all buildings owing to 24/7 operation, intensive ventilation and air filtration requirements, complex and varied thermal conditioning needs, the extensive and expanding use of electronic medical equipment, disinfection and other special processes, and the life-safety imperative of interrupted building operations [7]. When considering energy efficiency in hospitals, it is important to keep in mind that it is not the end-use of energy alone, but also the need to control indoor climate, that is one of the principal requirements. The indoor climatic requirements are determined by the hospital activities in the building. Once these are established, it is necessary to provide the required climate, ideally in the most economical way [1]. In practice, energy efficiency is increasingly becoming an important requirement, but medical considerations remain the top priority in the hospitals [1] and it is very important to attain both requirements at the same time. Since design, construct, and maintain a hospital building is complex it requires mastery of architecture, products and service offers. For all these reasons, this study focuses on energy performance evaluation methods of healthcare buildings.

In this study, the main aim is to show an appropriate calculation method for healthcare buildings. To this aim, energy performance tests of example hospital buildings have been done by using Turkish national building energy performance calculation method BEP-tr. However, since this method which is based on simplified energy certification methodology is not precise enough for healthcare buildings there is a need of another method to compare and improve Turkish national simulation method. For this reason, internationally recognized simulation tool Energy Plus is used as the second method. The calculation methodologies and their comparisons of these methods will be discussed in detail in the following parts.

1.2 Background Information

1.2.1 Energy efficiency in buildings

Energy is one of the important inputs for the development of the country [8]. Primary energy basically means calculated quantity of energy, taking into account the energy required outside of the building by the preceding process chains for obtaining, converting and distributing the respective fuels used, in addition to the energy content of the required fuel and the auxiliary energy for the technical building installations [9].

Delivered energy is used for heating, cooling, domestic hot water, lighting, and humidification. This includes the auxiliary energy required to operate the technical building installations [9].

%70 of energy requirement in Turkey is met by import, for this reason it is important to use the energy efficiently not to meet any barriers on industrialization and development. Also in Earth, while the need for energy is growing, energy resources are decreasing and so, efficient use of energy has become a vital matter. According to the studies done by relevant establishments, it is expected that 30% of the annual final energy consumption can be achieved as savings by efficient use of energy. This saving shows the importance of energy efficiency and relevant activities on this subject [8].

Energy efficiency, in other words energy performance means the evaluation of the energy quality of buildings by comparing calculated energy ratings against standard energy ratings (i.e. with economically viable energy ratings from comparable new or renovated buildings) or by comparing measured energy ratings against comparable values (i.e. with mean measured energy ratings from buildings with comparable types of usage) [9].

1.2.2 Sectorial allocation of annual energy demand

In Turkey, about 35% of energy and about 40% of total electricity consumption are used in building sector. Building sector takes the second place after industrial sector in energy consumption in Turkey. For this reason, the studies to ensure energy saving in buildings are vital for efficient use of energy resources [8]. However, according to the recent researches of Department of Energy USA (DOE), as in Figure 1.2 nowadays building sector takes the lead [10].

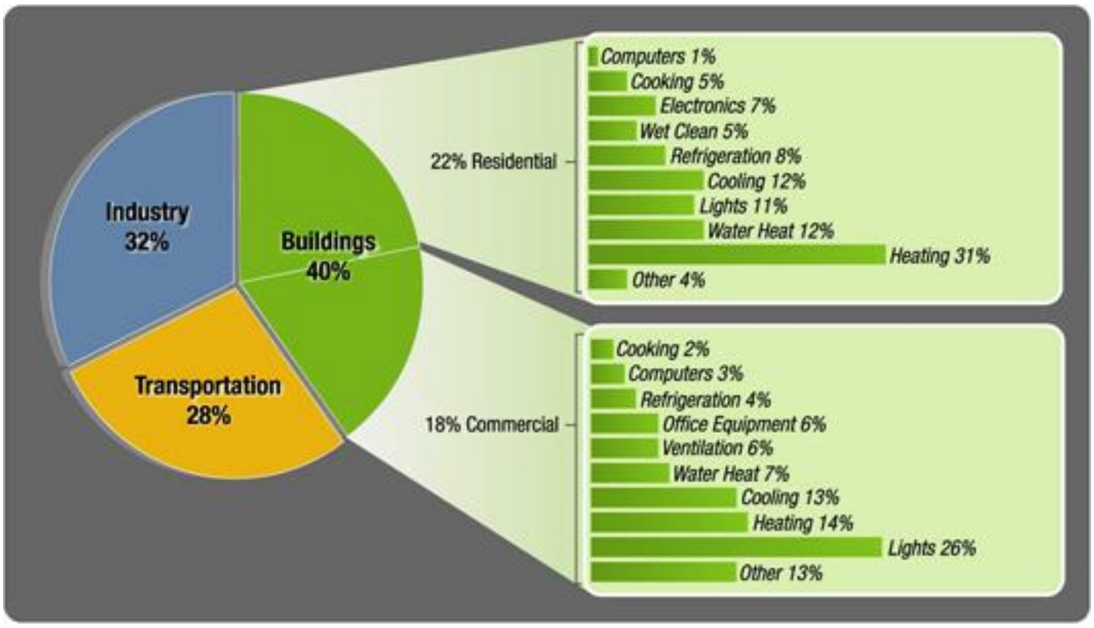


Figure 1.2 : Sectorial allocation according to the DOE researches [9].

In the relationship of building and energy the necessities as; efficient use and consumption of energy, appropriate equipment and system designs for efficient energy use, protection of used energy, recycling of waste energy to the system, etc. are highly important [8].

Renewable energy deployment has an important effect on primary and final energy consumption. A number of directives on renewable energy are already in place. New policies are likely to emerge at national level after the adoption of the climate change and energy package that includes an overall 20% target for renewables in the final energy consumption [6].

To use these resources properly in each sector it should be known that the annual energy consumption percent for each sector. In Figure 1.3 and 1.4 primary energy consumption and final energy consumption of renewable energy sources are shown according to EU-27.

The European Union is an economic and political union 0f 27 member states, which are located in Europe, and EU-27 is the name of this unity in EEA. EEA shares European environmental databases, maps, charts and applications.

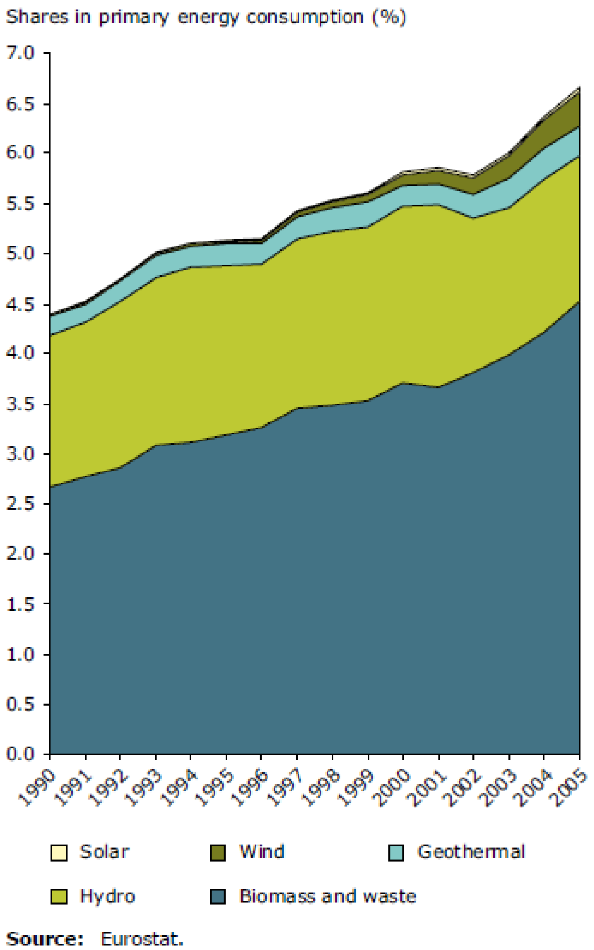
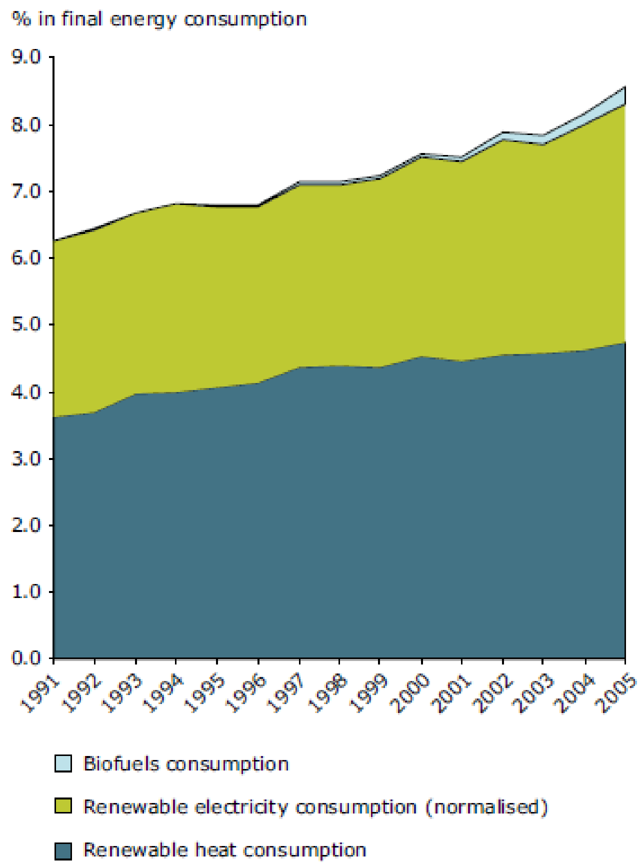


Figure 1.3 : Contribution of renewable energy sources to primary energy consumption in EU-27 [6].



Note: Hydropower was calculated according to the new methodology proposed in the CARE package (15-year average). It is important to note that the final methodology may be subject to further changes.

Source: Eurostat.

Figure 1.4 : Contribution of renewable energy sources to final energy consumption in EU-27 [6].

1.2.3 Building energy performance regulation in Turkey

Turkish Republic Ministry of Public Works and Settlement makes applications of automation ware engineering for necessary heating, cooling, ventilation, clean and waste water, lighting, and environment during the construction process of public utility buildings. However, in harmony with the current developments on energy it has become important to limit the energy consumption rates for heating, cooling, and lighting of the buildings accordingly it has become compulsory to make provisions for energy saving [8].

5627 Energy Efficiency Act is published in Turkish Official Gazette in 2 May 2007. The procedures and principles of this act include increasing and supporting energy efficiency in production, transmission and consumption stages of energy; in industrial enterprises; in buildings; in electrical power generation facilities; in transportation with transmission and distribution systems. They also include development of energy awareness in the society and utilization of renewable energy sources [11].

According to this act there are two regulation needs. One of them is Procedures and Principles Related to Building Energy Performance. This regulation should have been compatible to the EU Directive 2006/32/EC. In this case, it is important to analyze EPBD and the applications in EU countries on this issue.

The aim of EPBD is to increase the energy performance rates of the buildings in EU through considering external climate conditions, internal environmental needs, local conditions and relevant cost. This Directive includes [4]:

- A general view of a common method to calculate the total energy performance of buildings,
- Minimum requirements for the energy performance of all new buildings,
- Minimum requirements for the energy performance of large existing buildings subject to major renovation,
- Energy certification of all buildings,
- Regular mandatory inspection of boilers and air conditioning systems in buildings.

According to the Energy Performance of Buildings Directive, member states specify their building energy performance calculation methodologies based on this directive accordingly local conditions of each country. As a result of the calculation the energy performance level of the building will be obtained.

After this calculation, Member States will take the cautions to provide the minimum energy performance needs of the building. During this process, some categorization may be done for building types, for example basically new and old buildings.

The Building Energy Performance Regulation has been prepared to meet the requests of Energy Efficiency Act and EU Directive and it has been published in Turkish Official Gazette on 5 December 2008 again.

The calculation methodology that takes place in Building Energy Performance Regulation has been improved and the regulation has been published in Turkish

Official Gazette on 7 December 2010. Energy Certificates for buildings has been developed accordingly to the calculation methodology and it has been published as an annex in the regulation.

Nowadays the studies are going on to develop Building Energy Performance Turkey (BEP-tr). After obtaining the software, there will be competent authorities to draw up Energy Certificates [8].

1.2.4 Building energy certification

Basically, the certificate is a document containing information about specific thermal energy consumption related to heating, cooling, hot water installation, lighting, ventilation and climatization. Based on the calculated value of annual specific energy consumption (kWh/m^2a), the building is classified into a category of performance from A to G levels.

Detailed information about energy certification is existed in EN 15217 [12] and Building Energy Performance Regulation Turkey.

Energy certification procedures are enabling to produce an energy certificate. Energy certificate is a document recognized by a member state or a legal person designated by it, which includes the energy performance of a building [12]. The energy class levels (A to G) are to make it easy to understand in a metric way for indicating the energy performance of a building. Buildings that will be in a higher level on the metric scale should meet the energy performance requirement which is minimum level of energy performance that is to be achieved to obtain a right or an advantage.

To show the energy performance level of a building, there is a need of calculated energy rating which is an energy rating based on calculations of the weighted net delivered energy used annually by a building for heating, cooling, ventilation, domestic hot water and lighting [12].

1.2.4.1 Reference building

During the certification process, there is a need of a reference building to compare the existing or new building energy performance with it. Reference value basically means standard legal or calculated value against which an energy indicator is compared [12].

Reference values are used to compare the energy performance of a given building to the energy performance of similar buildings. Different reference values shall be defined for classes of buildings having different functions as in heat balance method which will be disscussed later. The reference values are defined at the national or regional level [12].

1.2.4.2 Energy certificate

The energy certificate shall contain at least administrative and technical data. Technical data contains one overall indicator representing the energy performance; type of indicator used; reference values; information on the energy performance of main building and system components; recommendations for cost effective improvements; optionally, the energy performance class presented on a scale. The recommendations shall deal with improvement measures such as building envelope, technical systems; also measures of property management such as improvement of the operation and control of the building and technical systems [12].

1.3 The Structure of The Thesis

To the aim of the study, steps are followed. Firstly, the energy performance calculation methods are selected. In this case, BEP-tr is selected as representative of Simple Hourly Method and Energy Plus is selected as representative of Detailed Dynamic Method. Then, these methods are examined separately. Afterwards, to understand the needs of a healthcare building, the boundary conditions of a healthcare building are analyzed through a benchmark hospital building example in Energy Plus database. After these analyses, BEP-tr and Energy Plus input databases are compared to have extra information about the calculation boundaries of BEP-tr. These comparisons are done by analyzing an Operating Room zone and a Patient Room zone from the example hospital project in Energy Plus database. Therefore, the energy consumption rates of two different zones are also discussed. Later on, the calculation methodologies of BEP-tr and Energy Plus are compared through a specific zone in this hospital project. According to the analyses and results, a new determination about energy performance calculation algorithm of healthcare buildings is highlighted. This determination is mostly about how BEP-tr can improve more to be able to calculate energy performance of hospital buildings.

After understanding some of the differences in between the boundary condition inputs and calculation methodologies of the two methods as a next step, an existing hospital IVF Center project is analyzed both to show the realistic energy demands of each zone in a hospital building and the energy consumption value of a hospital building by using the appropriate standards. This existing project is tested both in Energy Plus and in BEP-tr to be able to show the differences of the two methods in a standard required case study.

Later on, as a realistic study CTO Hospital in Torino, Italy is analyzed with an energy manager by using Energy Plus to understand the current condition of existed hospitals that are not built appropriate to the energy performance standards.

At the end, similar zones from IVF Center project and CTO Torino project are compared in same climatic data to be able to compare a standard required case and current condition case input data and, also to be able to obtain how the input data can vary and how these data can effect annual heating and cooling demand results.

2. BUILDING ENERGY PERFORMANCE CALCULATION METHODS

According to EN ISO 13790, there are three different calculation methodologies. These methodologies are [13];

- Simple hourly method
- Monthly method
- Detailed dynamic method

Turkish national building energy performance calculation methodology BEP-tr bases on ‘Simple Hourly Method’. The second calculation method in this study Energy Plus bases on ‘Detailed Dynamic Method’.

2.1 Simple Hourly Method

This model is a simplification of dynamic simulation with the intention of same level of transparency, reproducibility and robustness as the monthly method with main advantage over the monthly method that the hourly time intervals enable direct input of hourly patterns. In addition, the model makes new development easy by using directly the physical behavior to be implemented and keeps an adequate level of accuracy, especially for room-conditioned buildings where the thermal dynamic of the room behavior is of high impact [13].

The method is based on an equivalent resistance-capacitance (R-C) model as in Figure 2.1. It uses an hourly time step and all building and system input data can be modified each hour using schedule tables (in general, on a weekly basis) [13].

The method makes a distinction between the internal air temperature and mean temperature of the internal (building zone facing) surfaces (mean radiant temperature). This enables its use in principle for thermal comfort checks and increases the accuracy of taking into account the radiative and convective parts of solar, lighting, and internal heat gains, although the results of the simple method at hourly level are not reliable [13].

The calculation method is based on simplifications of the heat transfer between the internal and external environment.

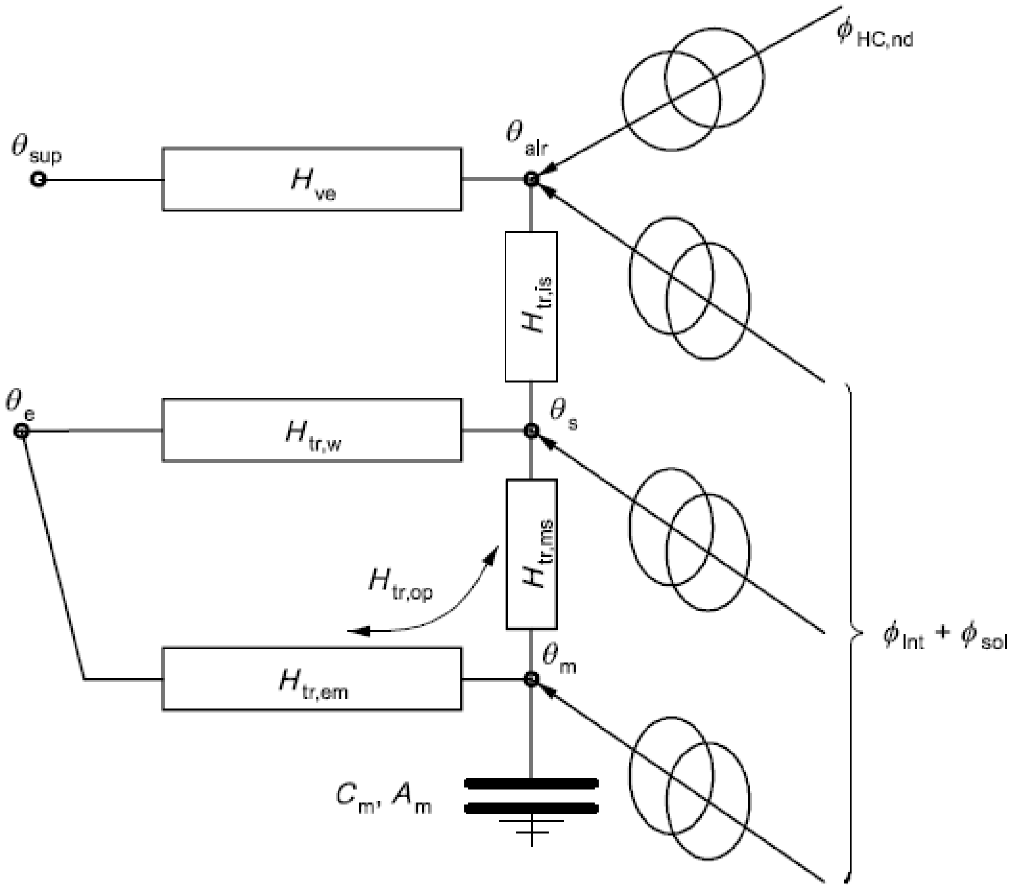


Figure 2.1 : Five resistances, one capacitance (5R1C) model [13].

2.2 Detailed Dynamic Method

Dynamic methods used for the calculation of energy need of heating and cooling shall have passed the validation tests in accordance with the relevant standards containing validation tests for detailed simulation methods [13].

Briefly, the calculation shall be performed according to partitioning into zones; transmission heat transfer characteristics; ventilation heat transfer characteristics; internal heat gains; solar heat gains; dynamic parameters; internal conditions. The calculation also includes dynamic heat transfer via the ground, including thermal bridges; non-adiabatic internal walls and floors; linear thermal bridges; air flows between building zones; solar shading by, and reflection from overhangs, fins and external obstacles; angle-dependent solar properties of windows; hourly calculation of air infiltration [13].

2.3 Building Energy Performance Calculation Method of Turkey (BEP-tr)

The last published version of BEP-tr includes five headlines. These are Net Energy Demand Calculation for Heating and Cooling, Lighting Energy Demand Calculation, Energy Demand Calculation for Mechanical Systems, Reference Building Designation Method, and Simplified Method for Existing Buildings.

The general calculation view of BEP-tr is shown in Figure 2.2 basing on EPBD. EPBD is another initiative of European Union as explained in detail Chapter 1.1.

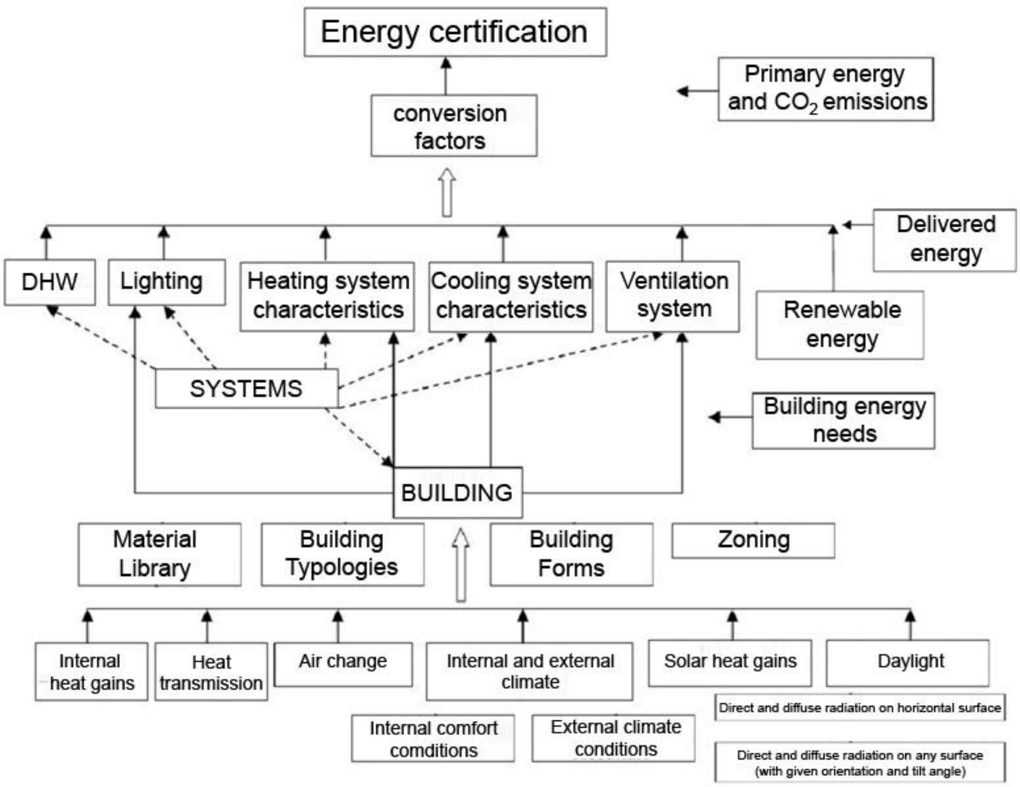


Figure 2.2 : General calculation method of BEP-tr basing on EPBD.

The main inputs for net energy demand calculation are as in Figure 2.3; climate data, building geometry, building's ventilation and thermal properties, internal heat gains and solar gains, definition of building materials and components, internal comfort conditions related to the building's typology (set-point values for temperature and humidity, ventilation rate), and zoning methods and zone properties.

According to the Simple Hourly Calculation, BEP-tr enables comfort conditions to be defined related to operative temperatures. It calculates net energy demand that is needed for hourly-calculated operative temperature and comfort conditions with hourly schedules.

BEP-tr takes solar gains, regarding the position of sun according to year, day and hour with the performance of solar shading devices into account. It considers heat loss to atmosphere with long wave radiation.

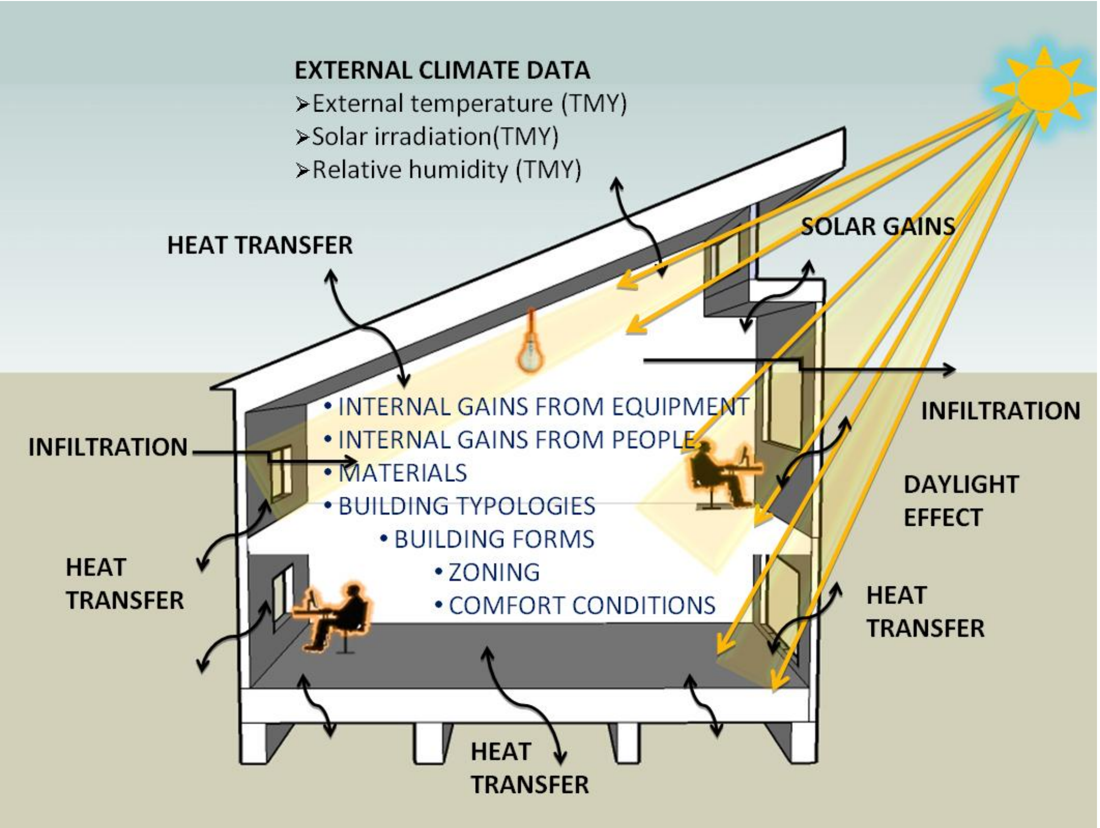


Figure 2.3 : Effective factors on building energy performance [14].

2.3.1 Building typologies

BEP-tr distinguishes buildings in typologies to have accurate energy demand inputs, since the input data change according to the each building function. These typologies are Residential Building (single-family houses, apartment blocks, residences) and Non-Residential Buildings.

2.3.2 Building geometry

Nowadays there is a test version of BEP-tr on web. As a beginning, it includes the basic building geometries to make the calculations easier, however BEP-tr methodology covers all kinds of building geometries. The selected basic forms are shown in Figure 2.4. In all forms, it has been adopted that surfaces are perpendicular to each other, for this reason generalizations are made for surfaces united with different angles. Building that requires energy demand calculation can be modeled by selecting nearest building form.

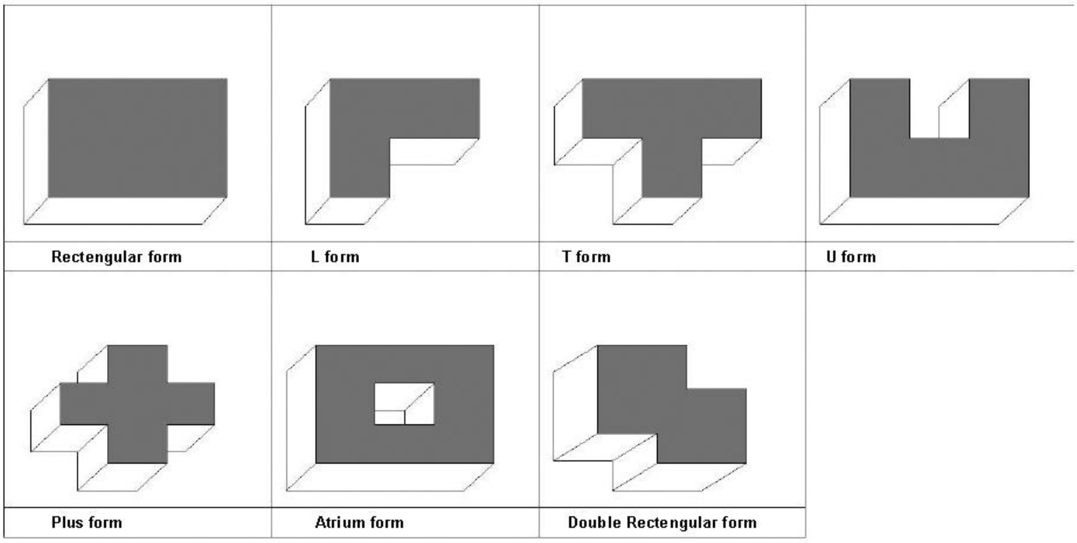


Figure 2.4 : Basic building forms [11]

2.3.3 Thermal zones

Spaces used in building split up into groups according to the thermal factors as running properties of heating, cooling, and ventilation systems; activity properties in the space; occupancy profiles; differences between internal heat gains. Each group with similar properties is named as ‘zone’ and each zone should be defined in the calculation method with its specific characteristics.

Zoning criteria differs in accordance with the building functions. However, for all functions since spaces between floors and obstacle condition may be differed, each floor is considered as a different zone even if they have the same internal gain and set-point values.

In BEP-tr for multi-zoning calculation without thermal coupling that is used in the methodology, heat transfer by convection, conduction, ventilation or infiltration between zones is not taken into account. Calculation is made separately for each zone taken into account as uncoupled zones. Energy demand for heating and cooling is the sum of calculated energy demand of each independent zone [11].

For typologies other than residential buildings and offices, each floor is taken as a single zone. Different space functions are defined by user and for each floor, an area weighted average internal gains and set-point temperatures for these functions are calculated to be used for the relevant floor. Since healthcare buildings are non-residential buildings in terms of energy certification, the main subject of this study, hospitals are tested by this method.

2.3.4 Calculation method

During the calculation process, BEP-tr takes into account heat transfer through transmission, heat transfer by ventilation, internal gains, and solar gains. This method meets the base equation of 'Energy Use for Space Heating and Cooling' accordingly EN ISO 13790. In this Chapter, only basic points of BEP-tr are summarized.

The heat transfer through transmission is explained in detail in EN ISO 13790 and BEP-tr Net Energy Report. In this study, the scheme of the idea is shown. As in Figure 2.5, the type of heat transmission is chosen on software as defined.

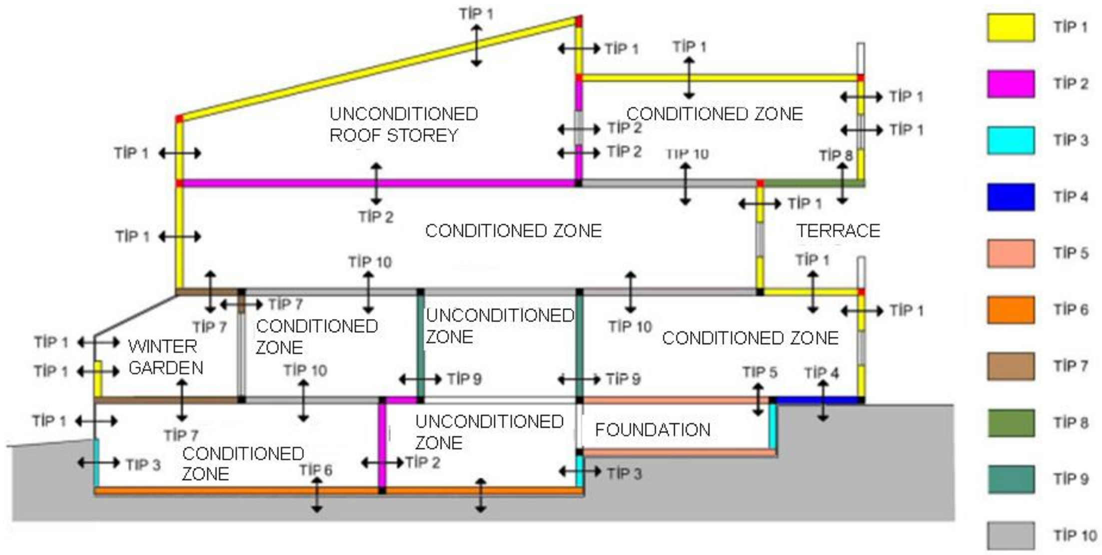


Figure 2.5 : Heat transfer through transmission [14].

Heat transfer by ventilation is explained in detail in EN ISO 13790 and BEP-tr Net Energy Report. In BEP-tr for heat transfer by ventilation, indirect effect on mass temperature and direct effect on internal air temperature of airflows generated by different sources in a specific zone are calculated.

Internal gains and solar gains are also explained in detail in EN ISO 13790 and BEP-tr Net Energy Report. Briefly, BEP-tr calculation methodology considers sensible and latent metabolic heat from occupants; sensible and latent heat gain from appliances; heat gain from lighting devices as internal gains.

Solar energy gains analyzed for opaque and transparent components separately. Methodology incorporates shading effect of external obstacles and building form, solar gains from effective collecting area of opaque and transparent components and heat loss to sky through thermal radiation.

2.4 Building Energy Performance Dynamic Calculation Through Energy Plus Simulation Tool

Real dynamic behaviour of buildings can be represented by transfer function or finite difference methods. These methods require simulation tools for applications. One of the well-known simulation tools to simulate dynamic behaviour of building is Energy Plus. In this study, for the comparison of Simple Hourly Method of BEP-tr and Dynamic Method, Energy Plus dynamic simulation tool has been used.

The concepts of modeling in Energy Plus include the zone heat balance process, air loop/plant loop process, and other important processes for the building simulation [15].

Energy Plus program is a collection of many program modules that work together to calculate the energy required for heating and cooling a building using a variety of systems and energy sources. It does this by simulating the building and associated energy systems when they are exposed to different environmental and operating conditions. The core of the simulation is a model of the building that is based on fundamental heat balance principles. FORTRAN code is used to describe the model. It turns out that the model itself is relatively simple compared with the data organization and control that is needed to simulate the great many combinations of system types, primary energy plant arrangements, schedules, and environments. Figure 2.6 shows this all organization in a schematic form [15].

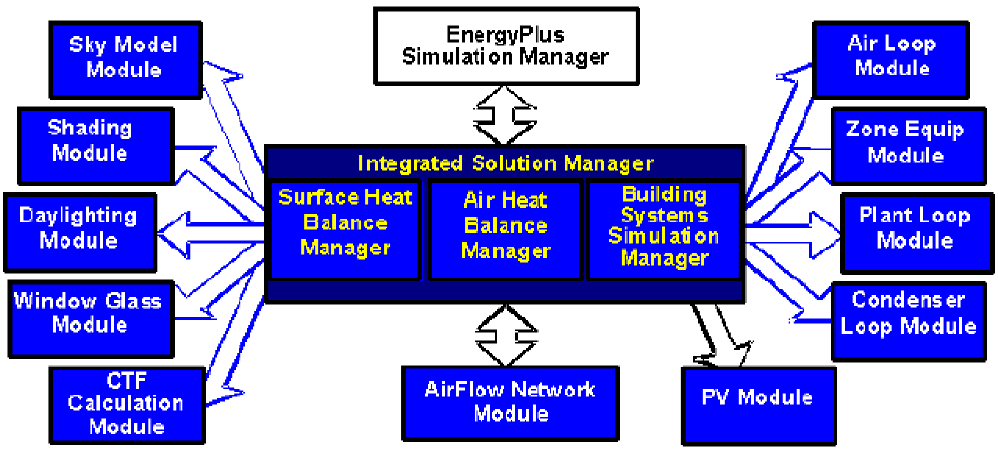


Figure 2.6 : Energy Plus Program Schematic [15].

Energy Plus is an integrated simulation. This means that all three of the major parts, building, system, and plant must be solved simultaneously. In programs with sequential simulation, such as BLAST and DOE-2, the building zones, air handling systems and central plant equipment are simulated sequentially with no feedback from one to the other. The sequential solution begins with a zone heat balance that updates the zone conditions and determines the heating/cooling loads at all time steps. This information is fed to the air handling simulation to determine the system response; but that response does not affect zone conditions. Similarly, the system information is passed to the plant simulation without feedback. This simulation technique works well when the system response is a well-defined function of the air temperature of the conditioned space. For a cooling situation, a typical supply and demand situation is shown schematically in Figure 2.7. Here, the operating point is at the intersection of the supply and demand curves [15].

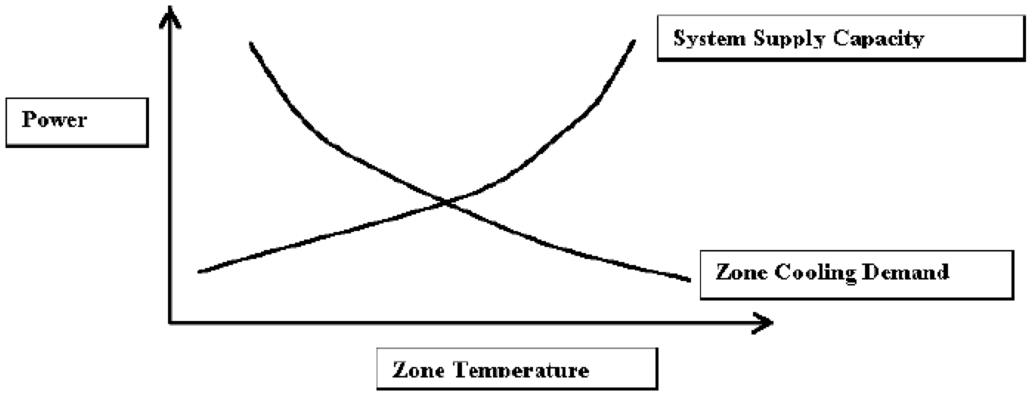


Figure 2.7 : Sequential simulation supply/demand relationship [15].

However, in most situations the system capacity is dependent on outside conditions and/or other parameters of the conditioned space. The simple supply and demand situation above becomes a more complex relationship and the system curve is not fixed. The solution should move up and down the demand curve. This doesn't happen in sequential simulation methods and the lack of feedback from the system to the building can lead to nonphysical results. For example, if the system provides too much cooling to a conditioned space excess is reported by the program as overcooling. Other categories of unmatched loads exist and are similarly reported by the program. While this kind of reporting enables the affected system or plant components to be properly sized, the system designer would, in most cases, prefer to see the actual change in zone temperature. The same mismatches can occur between the system and plant simulations when they are simulated sequentially [15].

To obtain a simulation that is physically realistic, the elements have to be linked in a simultaneous solution scheme. The entire integrated program can be represented as a series of functional elements connected by fluid loops as shown in Figure 2.8. In Energy Plus all the elements are integrated and controlled by the Integrated Solution Manager. The loops are divided into supply and demand sides, and the solution scheme generally relies on successive substitution iteration to reconcile supply and demand using the Gauss-Seidell philosophy of continuous updating [15].

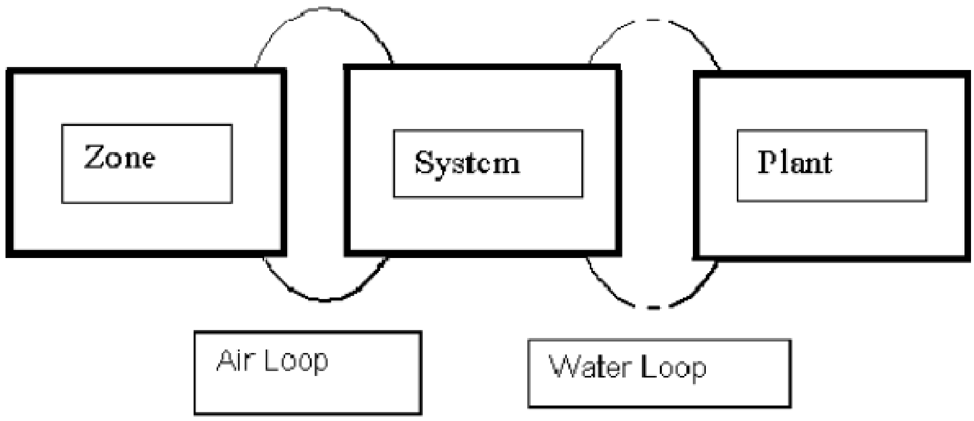


Figure 2.8 : Schematic of simultaneous solution scheme [15].

Energy Plus is a simulation tool that depends on Heat Balance Method and also a simplification of this method Radiant Time Series Method is implemented in Energy Plus [15].

2.4.1 Heat balance method

Cooling load estimation involves calculating a surface by surface conductive, convective, and radiative heat balance for each room surface and a convective heat balance for the room air. These principles form the foundation for Heat Balance method. The Heat Balance method solves the problem directly instead of introducing transformation-based procedures. The advantages are that it contains no arbitrarily set parameters, and no processes are hidden from view [16].

Some computations required by this rigorous approach require the use of computers. The heat balance procedure is not new. Many energy calculation programs have used it in some form [16].

2.4.1.1 Assumptions

All calculation procedures involve some kind of model; all models require simplifying assumptions and, therefore, are approximate. The most fundamental assumption is that the air in the thermal zone can be modeled as well mixed, meaning its temperature is uniform throughout the zone. The next major assumption is that the surfaces of the room (walls, windows, floor, etc.) can be treated as having uniform surface temperatures; uniform long-wave (LW) and short-wave (SW) irradiation; diffuse radiating surfaces; one dimensional heat conduction within [16].

The resulting formulation is called the heat balance (HB) model. The assumptions, although common, are quite restrictive and set certain limits on the information that can be obtained from the model [16].

2.4.1.2 Elements

Within the framework of the assumptions, the HB can be viewed as four district processes [16]:

- Outside face heat balance
- Wall conduction process
- Inside face heat balance
- Air heat balance

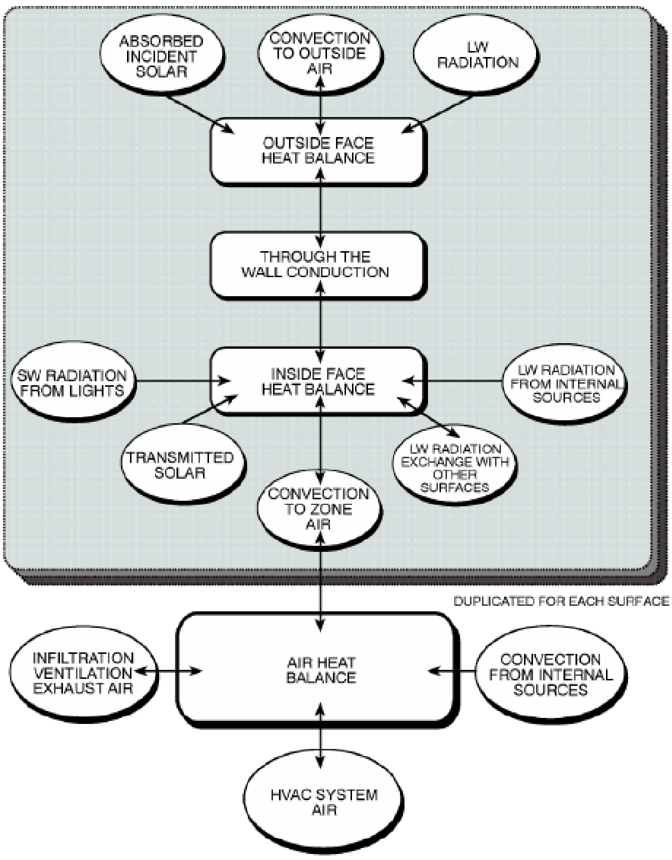


Figure 2.9 : Schematic of heat balance processes in a zone [16].

Figure 2.9 shows the relationship between these processes for a single opaque surface. The top part of the figure, inside the shaded bow, is repeated for each surface enclosing the zone. The process for transparent surfaces is similar, but the absorbed solar component appears in the conduction process block instead of at the outside face, and the absorbed component splits into inward and outward flowing fractions. These components participate in the surface heat balances [16].

2.4.1.3 Overall HB iterative solution

The iterative HB procedure consists of a series of initial calculations that proceed sequentially, followed by a double iteration loop, as shown in the following steps [16]:

1. Initialize areas, properties, and face temperatures for all surfaces, 24 h.
2. Calculate incident and transmitted solar flux for all surfaces and hours.
3. Distribute transmitted solar energy to all inside faces, 24 h.
4. Calculate internal load quantities for all 24 h.
5. Distribute LW, SW, and convective energy from internal loads to all surfaces for all hours.
6. Calculate infiltration and ventilation loads for all hours.
7. Iterate the heat balance according to the following scheme:

```
For Day = 1 to Maxdays
    For j = 1 to 24                    {hours in the day}
        For SurfaceIter = 1 to MaxIter
            For i = 1 to 12            {The twelve zone surfaces}
                Evaluate Equations (34) and (35)
            Next i
        Next SurfaceIter
        Evaluate Equation (36)
    Next j
If not converged, Next Day
```

8. Display results.

Generally, four or six surface iterations are sufficient to provide convergence. The convergence check on the day iteration should be based on the difference between the inside and outside conductive heat flux terms [16].

2.4.1.4 Input required

This method generally tended to reduce the amount of information required to apply the procedure. With heat balance, no precalculations are made, so the procedure requires a fairly complete description of the zone. The required input data are [16]:

1. Global information
2. Wall information (each wall)
    - Facing angle with respect to solar exposure
    - Tilt (degrees from horizontal)
    - Area
    - Solar absorptivity outside
    - LW emissivity outside
    - SW absorptivity inside
    - LW emissivity inside
    - Exterior boundary temperature condition (solar versus non-solar)
    - External roughness
    - Layer by layer construction information
3. Window information (each window)
    - Area
    - Normal solar transmissivity
    - Normal Solar Heat Gain Coefficient (SHGC)
    - Normal total absorptivity
    - LW emissivity outside
    - LW emissivity inside
    - Surface to surface thermal conductance
    - Reveal (for solar shading)
    - Overhang width (for solar shading)
    - Distance from overhang to window (for solar shading)
4. Roof and floor details
5. Thermal mass surface details
6. Internal heat gain details

7. Radiant distribution functions
8. Other required information

2.4.2 Radiant time series (RTS) method

The radiant time series (RTS) method is a simplified method for performing design cooling load calculations that is derived from the heat balance (HB) method. It effectively replaces all other simplified (non-heat balance) methods [16].

This method was developed to offer a method that is rigorous, yet does not require iterative calculation, and that quantifies each component's contribution to the total cooling load [16].

The RTS method is suitable for peak design load calculations, but it should not be used for annual energy simulations because of its inherent limiting assumptions.

2.4.2.1 Assumptions and principles

Design cooling loads are based on the assumption of the steady periodic conditions (i.e., the design day's weather, occupancy, and heat gain conditions are identical 24 h cyclical basis). Thus, the heat gain for a particular component at a particular hour is the same as 24 h prior, which is the same as 48 h prior, etc. This assumption is the basis for the RTS derivation from the HB method [16].

2.4.2.2 Overview

Figure 2.10 gives an overview of the RTS method. In the calculation of solar radiation, transmitted solar heat gain through windows, sol-air temperature, and infiltration, RTS is exactly the same as other simplified methods. Important areas differ from previous simplified methods include computation of conductive heat gain; splitting of all heat gains into radiant and convective portions; conversion of radiant heat gains into cooling loads [16].

The RTS method accounts for both conduction time delay and radiant time delay effects by multiplying hourly heat gains by 24 h time series. The time series multiplication, in effect, distributes heat gains over time. Series coefficients, which are called radiant time factors and conduction time factors, are derived using the HB method. Radiant time factors reflect the percentage of an earlier radiant heat gain that becomes cooling load during the current hour [16].

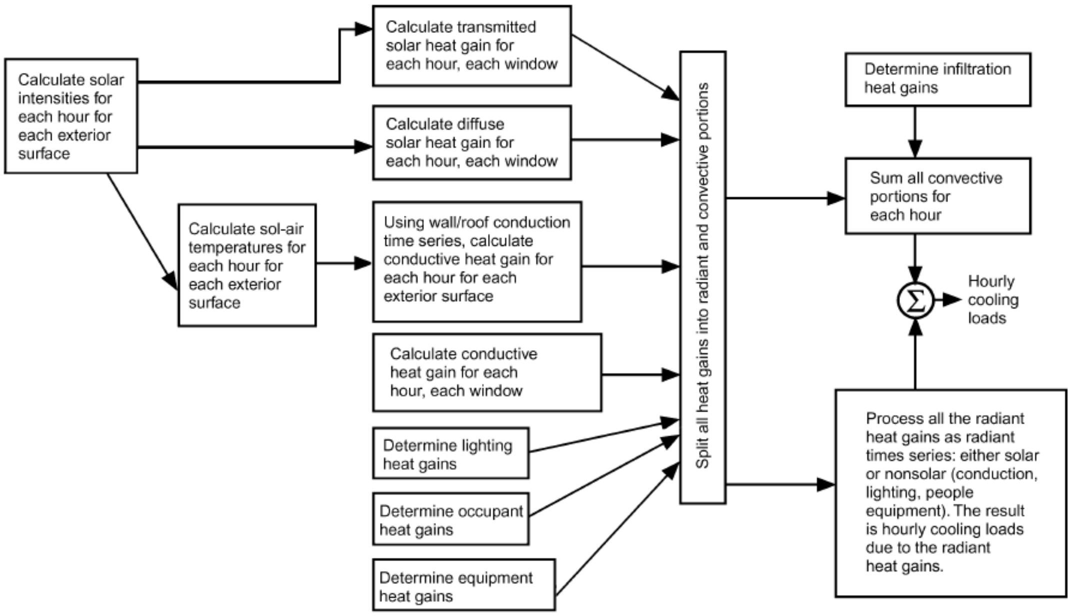


Figure 2.10 : Overview of radiant time series method [16].

These series can be used to easily compare the time-delay impact of one construction versus another. This ability to compare choices is of particular benefit in the design process. Comparison can illustrate the magnitude of difference between the choices, allowing the engineer to apply judgement and make more informed assumptions in estimating the load [16].

2.4.2.3 RTS procedure

The general procedure for calculating cooling load for each load component (lights, people, walls, roofs, windows, appliances, etc.) with RTS is as follows [16]:

1. Calculate 24 h profile of component heat gains for design day (for conduction, first account for conduction time delay by applying conduction time series).
2. Split heat gains into radiant and convective parts.
3. Apply appropriate radiant time series to radiant part of heat gains to account for time delay in conversion to cooling load.
4. Sum convective part of heat gain and delayed radiant part of heat gain to determine cooling load for each hour for each cooling load component.

After calculating cooling loads for each component for each hour, sum those to determine the total cooling load for each hour and select the hour with the peak load for design of the air-conditioning system. Repeat this process for multiple design months to determine the month when the peak load occurs, especially with windows on southern exposures, which can result in higher peak room cooling loads in winter months than in summer [16].

A lot of tests are done to compare the results of RTS method with HB method. Except some specific cases, tests under more typical conditions (venetian blinds, carpeted floor, office type furnishings, and normal internal loads) provided good agreement between HB, RTS, and measured loads [16].

3. COMPARISON BETWEEN DYNAMIC AND SIMPLIFIED SIMULATION METHODS FOR HOSPITAL BUILDINGS

According to the aim of this study, the main goal is to analyze the net energy demand of hospital buildings and to investigate the most appropriate method to obtain realistic annual heating and cooling demand results of healthcare buildings. To obtain dependable energy demand rates of healthcare buildings it is important to investigate the energy calculation methodologies of dynamic and simplified energy performance calculation algorithms. A realistic method should be chosen to attain the current results and recommend efficiency procedures.

For this reason, in this study Energy Plus as a dynamic tool and BEP-tr as a simplified method are compared. While comparing simulation methods, boundary conditions as input data and calculation methodologies should be considered. To this aim, a benchmark hospital building example is analyzed from Energy Plus database. Since BEP-tr is the Turkish National Simulation Method, the energy performance of the building is tested in Istanbul climate.

To do the analysis, the benchmark hospital building project in Energy Plus database in Figure 3.1 is examined.

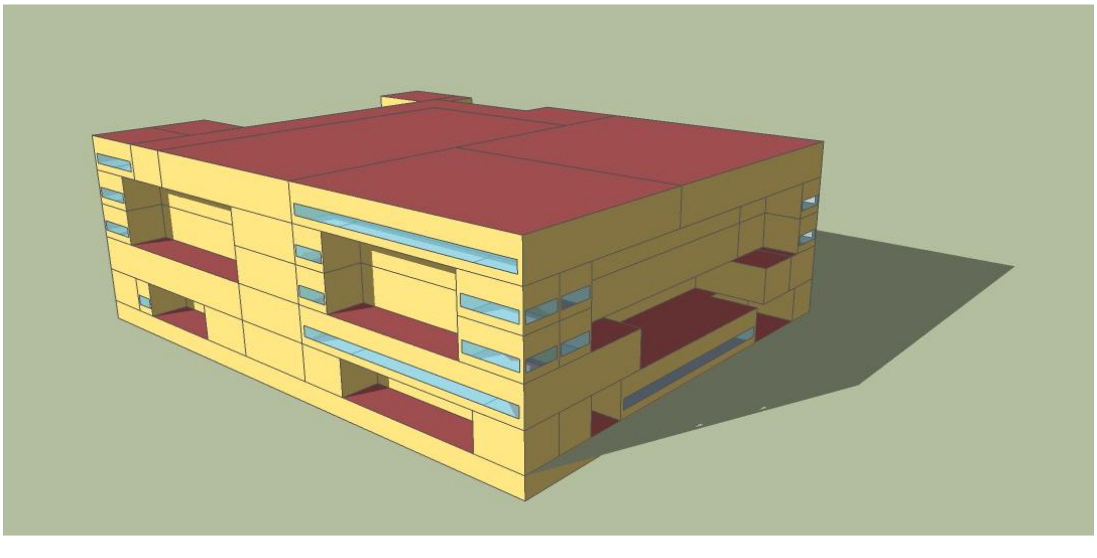


Figure 3.1 : Energy Plus benchmark hospital building

3.1 Comparison of Boundary Conditions

In this phase of comparison, BEP-tr and Energy Plus are compared over boundary conditions. Boundary conditions are among the most important input data to analyze the heating and cooling energy demand of the building.

$$Q_{ht} = (Q_{tr} + Q_{ve}) - (Q_{sol} + Q_{ig}) \qquad \textbf{(3.1)}$$

Equation 3.1 shows the terms that have to be assessed according to the boundary condition data. These terms consist of: transmission, ventilation heat exchange, solar gain, and internal gains. During the simulation tests, it is realized that for a building with high internal gain rates as hospitals, the most important input data are ventilation and internal gains. The reason of this will be discussed in the results.

Internal heat gains from people, lights, and equipments can contribute the majority of the cooling load in a modern building. In general, as building envelopes have improved in response to more restrictive energy codes, internal loads have increased because of factors such as increased use of computers and the advent of dense-occupancy spaces. Internal heat gain calculation techniques are identical for each calculation method [16].

To compare the boundary condition data of Energy Plus and BEP-tr an Operating Room and a Patient Room are analyzed in the benchmark project from Energy Plus database. The Operating Room locates at the second floor of the building with North and East external facades. The Patient Room locates at the third floor of the building with South and East external facades. Operating Room is in the sterilized part of the hospital and according to the Turkish Republic Private Hospitals Regulation, because of the hygienic reasons there is no transparent components in operating rooms. The risk of contamination is so high in accordance with the activity in these rooms. Only hygienic mechanical ventilation is required, natural ventilation and daylight are not appropriate in operating rooms. Patient Room is not in the sterilized part of the hospital and it includes transparent components for natural ventilation and daylight. Therefore, in this phase of comparisons while the boundary condition data of Energy Plus and BEP-tr are investigating, also the boundary condition data of two zones in different conditions in a hospital are compared. Operating Room and Patient Room zones are shown respectively in Figure 3.2 and 3.3.

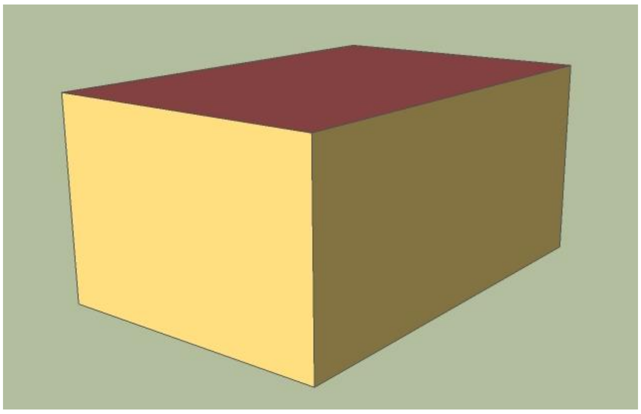


Figure 3.2 : Benchmark hospital building – Operating Room

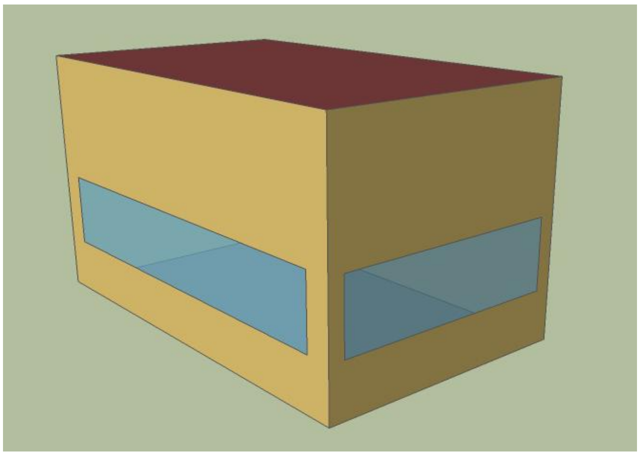


Figure 3.3 : Benchmark hospital building – Patient Room

Operating Room and Patient Room zones have same opaque envelope components as in Table 3.1.

Table 3.1: Opaque building components for Operating and Patient Rooms

Layer Name	Material	Thickness (d)-m	Conductivity (λ)-W/m-K
External Wall	1 IN Stucco	0.025	0.69
Layers	8 IN Concrete HW	0.20	1.31
	Mass NonRes Wall Ins.	0.05	0.05
	½ IN Gypsum	0.0127	0.16
Internal Wall	½ IN Gypsum	0.0127	0.16
Layers	½ IN Gypsum	0.0127	0.16
Internal Floor	Carpet Pad		
Layers	MAT-CC05 4HW Concrete	0.10	1.31

Patient Room has transparent envelope components too as shown in Table 3.2. Natural ventilation and daylight are very important factors in patient rooms for patient comfort and healing process.

Table 3.2: Transparent building components for Patient Room

Layer Name	Material	U-factor-W/m^2K	SHGC
Window Layers	ASHRAE Res Fixed Assembly Window	3.23	0.39

Table 3.3 shows remarkable differences especially in terms of amount of internal gains and ventilation airflow rate. However, it is important to underline that the set of input data is complete in BEP-tr for residential and office buildings, while for a complex building as in this case for a hospital building there are some missing data.

Table 3.3: Comparison of data of Energy Plus and BEP-tr

Boundary Conditions $Q_{space}=(Q_{TR}+Q_{ventilation})-(Q_{solar}+Q_{internal\ gains})$	Unit	Energy Plus		BEP-tr	
		Operating Room	Patient Room	Operating Room	Patient Room
Q_{TR} walls, $U_{op,\ stnd}$	W/m^2K	0.7	0.7	0.7	0.7
Q_{TR} windows, U_{win}	W/m^2K	No win.	3.24	No win.	---
Outdoor air flow per zone	m^3/s	0.2	0.08	---	---
Outdoor air flow per zone (per person)	m^3/ph	240	144	---	30
Air Change Rate per Hour	1/h	3	1.93	---	---
Internal Gains [17]					
People (sensible heat gain)	W/p	91	80.34	---	---
	W/m^2	4.9	6.9	10.7	---
People (latent heat gain)	W/p	29	39.7	---	---
	W/m^2	1.6	3.4	5.35	---
TOTAL	W	360	240	900.2	---
Max number of person	p	3	2	7	---
Lights (per m^2)	W/m^2	23.7	7.5	---	---
TOTAL	W	1328.4	263.25	---	---
Electric Equipment (per m^2)	W/m^2	43	21.5	0.92	---
TOTAL	W	2415.4	752.3	51.6	---
Temperature set-point					
Heating set-point	°C	18.3	21.1	20	24
Cooling set-point	°C	18.3-22.2	22.2	26	24

In the table, the areas shown in yellow are the data that do not exist in BEP-tr database for Operating Room and Patient Room zones. In addition, when the existed data in BEP-tr database are compared with the existed data in Energy Plus database it can be seen that these data are very different than the existed data in Energy Plus database. BEP-tr data for hospitals are prepared basing on European Standards and the reason that these data are missing or different in BEP-tr database is because they are also missing or different in European Standards.

Moreover, it is obvious in the table that the internal gains of Operating Room zone are higher than the internal gains of Patient Room zone. In hospitals, there are a lot of zones that have a high difference in between amount of their internal heat gains.

After realizing that both methods have different boundary condition data in their databases there happened a need to compare the effect of these differences on annual heating and cooling demands. All of the boundary condition data have a significant effect on annual heating and cooling demands and to show this effect the temperature set-point values, which are crucial and different for each zone like the other input parameters in a healthcare building, are tested. These values depend on the activity and type of patient in the zone. This is a sort of sensitivity analysis to show how much it is important for the results to select the right value.

The annual heating and cooling demands, obviously vary according to the selected temperature set-point. This parameter plays a significant role on the different heating and cooling demands of the different zones. To show the possible range of variation of the heating and cooling demands according to the selected temperature set-point values, three cases for the Operating Room zone are tested in Energy Plus with reference to Istanbul outdoor climate. The results are presented in Table 3.4. Due to high internal gains and high thermal resistance of external walls, only cooling demand is assessed by the calculations.

As shown in the Table 3.4, when the temperature set-point value is 20 °C constant, the annual cooling demand is 379 kWh/m²a. When the temperature set-point value in Energy Plus database is used, this value changes -10% and when the temperature set-point value in BEP-tr database is used this value changes -27%. These variations in the results occur just with one input parameter. However, there are a lot of input parameters under the name of boundary conditions (such as: temperature set-point, internal gains, ventilation). Therefore, it is very important to use right values to be able to obtain realistic results.

Table 3.4: Annual heating and cooling demand in the tested Operating Room as a function of different temperature set-point values

Temperature set-point value	Annual Heating Demand (kWh/m^2a)	Annual Cooling Demand (kWh/m^2a)
20-20 °C Constant set-point value	0	379 (---)
18.3-22.2 °C Suggested set-point values in Energy Plus database	0	341 (-10%)
20-26 °C Suggested set-point values in BEP-tr database	0	275 (-27%)

3.1.1 Results

BEP-tr bases on EN standards as reference for healthcare buildings. Some of the input data for healthcare buildings do not exist in EN standards. Therefore, that is the reason of the missing input data of BEP-tr in Table 3.3.

Both in Energy Plus and in BEP-tr, heat transmission depends on the building envelope components. Energy Plus and BEP-tr have their own material libraries to select the components that used in calculations. Solar gains depend on the direction of the building/zone and the climatic data. Since Energy Plus is a dynamic tool, it uses a detailed climatic data while BEP-tr uses national climatic data.

Air change rate is a very important input for healthcare buildings for both hygienic and energy demand reasons. This data is specified in ASHRAE standards for each specific zone of a healthcare building [18]. Table 3.3 shows the existing data in BEP-tr database.

Internal gains are crucial data for healthcare buildings. In each thermal zone, this data changes according to the activity level of the zone. Energy Plus data exist for each zone in the tool database. As mentioned before, BEP-tr does not have these data because of the reference EN standards.

In addition, ASHRAE standards have the data for example, for a general operating room or for a general laboratory. However, there are a lot of branch hospitals and for branch type boundary condition data, detailed research should be carried out. Moreover, as ASHRAE Handbook 2005 suggests, especially for characterized medical equipment, manufacturers can help on this subject. In the terms of input data, BEP-tr can make use of various standards with EN standards and, also Turkey should improve its standards about this subject.

3.2 Comparison of Calculation Algorithms

As mentioned in Chapter 1, the calculation methodologies of Energy Plus and BEP-tr are different. In the cases as residential buildings, this difference is not a problem for energy performance calculations. There are lots of default values for residential buildings and also, the difference of calculation methodologies is not a crucial factor in this case.

In the case of non-residential/complex buildings, the calculation methodology is an important factor together with the input data. Because as in the comparison of Operating Room and Patient Room zones there are a lot of thermal zones in hospital buildings which have variations in their thermal behaviours. To evaluate these entire different thermal zones together, integrated simulation tools that calculate building, system, and plant simultaneously can be used. Energy Plus is an integrated simulation tool. In methods with sequential simulation, the building zones, air handling systems, and central plant equipment are simulated sequentially with no feedback from one to other [15]. This study focuses on space heating and cooling demand without systems and plant. The system is analyzed as equipped an ideal all air system.

As shown in Chapter 3.1 there are differences between the input data of both methods. To compare the calculation methodologies of both methods, the input data used in tests should be same. For this reason, Energy Plus input data which are complete are taken as reference values to be used in this phase of tests. There are two air change per hour data in tests, of course operating rooms have just one air change per hour data, however this is in order to highlight the building envelope heating and cooling energy demand without ventilation since these are sensitivity analysis. Opaque building components that shown in Table 3.1 are used as reference in tests, since tests are done for Operating Room zone there is no transparent component. In fact, BEP-tr has a complete material library, but the data used in both methods during the tests should be the same to be able to compare calculation methodologies, so Energy Plus building components are used.

Eight cases are tested for the Operating Room of the benchmark hospital project of Energy Plus. Table 3.5 shows these cases in detail. Cases are grouped as three investigation groups.

In all case groups, the main aim is to show the effect of the differences of calculation methodologies used by Energy Plus and BEP-tr. This effect is shown in the results of each case by using the same boundary condition data and obtaining different tendencies on heating and cooling demands.

Table 3.5: Characteristics of analysed case studies for Operating Room

Changing Parameters	Case Name	Case Description
Air Change Rate per Hour=0 h^{-1} Temperature set-point value=20 °C (Results in Table 3.6 & Figure 3.4)	Case 1 Case 2 Case 3	Simulation by Energy Plus Simulation by BEP-tr Simulation by BEP-tr, but by taking solar gains “0 W”
Air Change Rate per Hour=0 h^{-1} Temperature set-point value=20 °C (Results in Table 3.7 & Figure 3.5)	Case 4 Case 5 Case 6	Simulation by Energy Plus Simulation by BEP-tr Simulation by BEP-tr, but by taking solar gains “0 W”
BEP-tr equation: $\Phi_m = (A_m/A_{tot}) * (0.5 * \Phi_{int} + \Phi_{sol})$ has been changed into: $\Phi_m = (A_m/A_{tot}) * (0.7 * \Phi_{int} + \Phi_{sol})$ Temperature set-point value=20 °C (Results in Table 3.8 & Figure 3.6)	Case 7 Case 8	Simulation by BEP-tr and Air Change Rate per Hour=0 h^{-1} Simulaton by BEP-tr and Air Change Rate per Hour=3 h^{-1}

In all the cases, possible heat recovery on ventilation air is not considered at this stage of analysis.

In the first investigation group, the effects of boundary conditions and solar gains on Annual Heating and Cooling demands are evaluated by taking ventilation value “0 1/h” and set-point temperature value 20 °C constant. In this case, it is accepted that there is no ventilation in the zone. In a zone as Operating Room with no transparent components and with high internal gains, medical equipment and characteristic lighting are the most important thermal flux in the energy balance of the zone. In Case 3 of first investigation group, solar gains are taken “0 W” to examine the effect of heat gain/loss through transmission on results for Operating Room zone. As shown in Table 3.6, cases 1 and 2 have the same input data but the results are different. However, both methods have the same tendency of heating and cooling.

Table 3.6: First investigations: results for the Operating Room

Operating Room		Unit	Case 1 (E+)	Case 2 (BEP-tr)	Case 3 (BEP-tr)
Boundary Conditions	Heating set-point	°C	20	20	20
	Cooling set-point	°C	20	20	20
	Sensible heat gain from people [16]	W/m^2	4.9	4.9	4.9
	Latent heat gain from people [16]	W/m^2	1.6	1.6	1.6
	Internal heat gain from lighting	W/m^2	23.7	23.7	23.7
	Internal heat gain from equipment	W/m^2	43	43	43
	Air change rate per hour	1/h	0	0	0
Annual Energy Demand	Annual Heating Demand	kWh/m^2a	0	0	0
	Annual Cooling Demand	kWh/m^2a	571	702	696

As expected, high cooling demands are evaluated due to high internal gains and low heat losses. In Operating Room, medical equipment and characteristic lighting are the most important internal gain parameters. Since there is no ventilation value in these cases it is normal to have almost no heating demand and a very high cooling demand. The effect of the thermal behavior of the envelope is tested with “Case 3” by taking solar gains “0 W”. As a result of “Case 3” a little reduction in Cooling Demand is investigated as in Table 3.6. In a zone with high internal gains like Operating Room the heat transfer from the building envelope does not have an important effect on annual heating and cooling demands. It should also be considered that Operating Room doesn’t have any transparent components. Since, this reduction has a small rate in comparison to “Case 2”, as it is determined before, it is confirmed that the reason of high cooling demands are the high internal gain rates in the Operating Room zone.

The results are shown as diagrams in Figure 3.4. As shown in the figure, there is no heating demand in all cases. While the cooling demand need is 571 kWh/m^2a in

Energy Plus tests, it is 702 kWh/m^{2}a in BEP-tr. It is important to show that BEP-tr result changes in to 696 kWh/m^{2}a when there is no solar gain, as mentioned above, this numeric results prove that in zones with high internal gains, the most important parameter is internal gain.

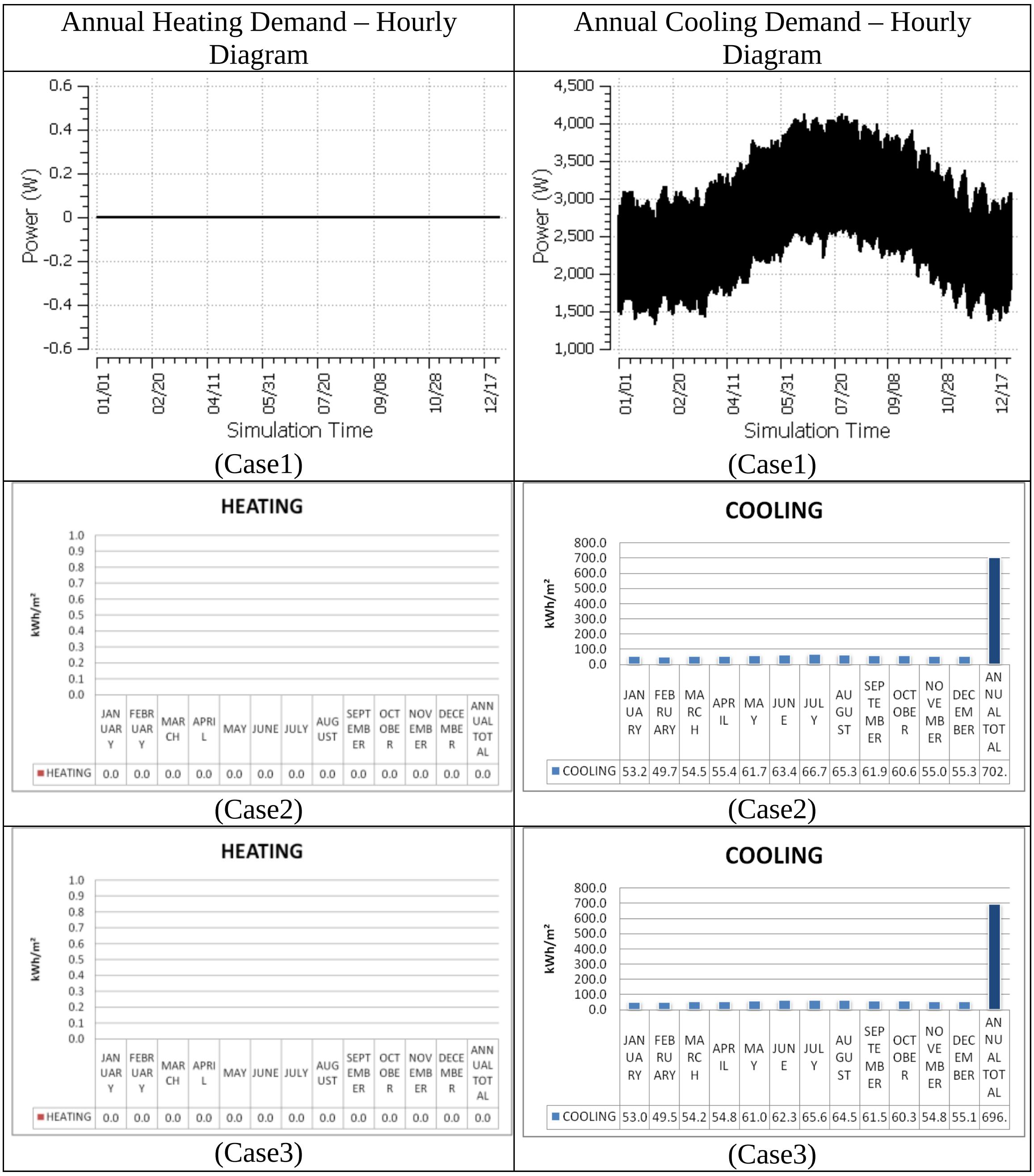


Figure 3.4 : First investigations: diagram results for the Operating Room

In the second investigation group, the air change rate per hour value is fixed at “3 1/h” as suggested in Energy Plus database for the Operating Room and the tests are done by using the same boundary conditions of the first investigation group also to investigate the effect of air change rate per hour data on annual heating and cooling demand results. Since there is a ventilation data in this phase of tests a little increase on annual heating demand and a reduction on annual cooling demand are expected in compare to the first investigation group. Thus as in Table 3.7, there is a little increase in annual heating demand (Case 4) and a reduction in annual cooling demand (Case 4) in Energy Plus results in comparison to Case 1 results.

As expected, air change data has an effect on annual cooling demand and it reduces the cooling demand. Since it is a specific Operating Room case, internal heat gains are highly effective on the results and still there is a high cooling need. However, the increase rate on annual heating demand and decrease rate on annual cooling demand are too sharp in BEP-tr results. Even with these high internal heat gain rates, BEP-tr tends to underestimate the cooling load and overestimate the heating load for this case study. In this case, it is observed that the sensitivity to internal gains is not sufficient and the sensitivity to the ventilation coefficient is more in BEP-tr. For this reason, since internal gains are dominant for the thermal balance of the test zone Operating Room, it is checked that whether internal gains are represented sufficiently in EN 13790 since BEP-tr algorithm bases on this standard (Cases 7 and 8).

Table 3.7: Second investigations: results for the Operating Room

Operating Room		Unit	Case 4 (E+)	Case 5 (BEP-tr)	Case 6 (BEP-tr)
Boundary Conditions	Heating set-point	°C	20	20	20
	Cooling set-point	°C	20	20	20
	Sensible heat gain from people [16]	W/m^2	4.9	4.9	4.9
	Latent heat gain from people [16]	W/m^2	1.6	1.6	1.6
	Internal heat gain from lighting	W/m^2	23.7	23.7	23.7
	Internal heat gain from equipment	W/m^2	43	43	43
	Air change rate per hour	1/h	3	3	3
Annual Energy Demand	Annual Heating Demand	kWh/m^{2}a	0.1	3	4
	Annual Cooling Demand	kWh/m^{2}a	379	173	167

Additionally, the tendency of the results is the same with the first investigation group. Results of Case 6 with a little difference in comparison to Case 5 show that the heat gain/loss through the building envelope does not have an important effect on annual heating and cooling demands for Operating Room.

The results of the second group are shown in diagrams in Figure 3.5.

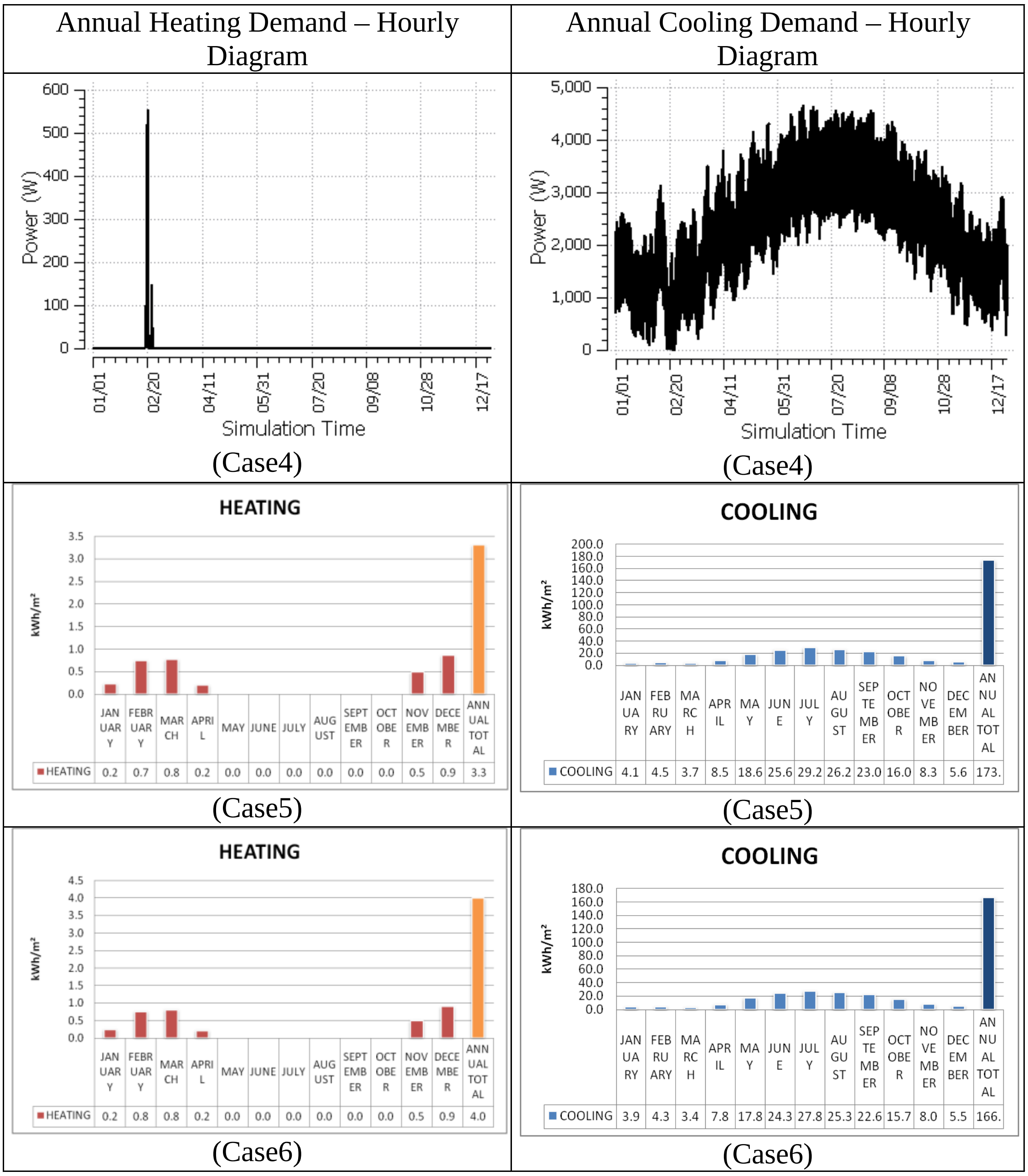


Figure 3.5 : Second investigations: diagram results for the Operating Room

The third investigation group, cases 7 and 8, is formed with the aim of analysing the reason of different results of second investigation group. As mentioned before the sensitivity to internal gains are not sufficient enough in BEP-tr and for this reason the calculation methodologies of Energy Plus and BEP-tr are examined in detail. In the second investigation group, despite an infiltration rate value is added, there should be a high cooling demand as in Energy Plus result (Case 4) according to internal heat loads. Since these results are not supported by BEP-tr results, the third investigation group is prepared to prove the effect of the calculation methodology differences on results.

Since BEP-tr results are in harmony with boundary condition data changes, the algorithm of the method is analysed and compared with the algorithm of Energy Plus by analysing the equations in EN 13790. It is obtained that the annual heating and cooling demand results are different in comparison to Energy Plus results because of the simplification in BEP-tr's calculation methodology.

As shown in Table 3.7 and Figure 3.5, annual heating demand results are higher when calculations are done by BEP-tr because of the thermal behaviour of the building is calculated by a simplified method which is obtained from EN 13790. In particular, instantaneous loads through the opaque envelope are higher in BEP-tr because BEP-tr tends to underestimate the storage effect in comparison to Energy Plus [15]. Therefore, the effect of heat transmission and heat storage through opaque envelope change, thus Energy Plus is able to simulate the heat storage dynamics in a better way. Moreover, Energy Plus considers the radiative and convective gains while calculating the solar gains and to this aim, it uses different coefficients to multiply with the total solar gain and presents the difference in between the radiative and convective heat gains. In addition, in BEP-tr a simplification method suggested by EN standards is adopted to take into account internal and solar gains. In this case, BEP-tr tends to distribute the solar gains Φ_{sol} to the space and solar gain is multiplied with A_m / A_{tot} value which is a lower value than "1", thus solar gain is reduced [13]. In particular, internal and solar gains are treated in BEP-tr as follows:

$$\Phi_m = (A_m / A_{tot}) * (0.5 * \Phi_{int} + \Phi_{sol}) \qquad \textbf{(3.2)}$$

In eq. 3.2 Φ_m represents the heat flow from internal and solar heat sources in Watt. A_m represents the useful surface area in m² and A_{tot} represents the area of all surfaces facing the room in m² [13]. Φ_{int} represents the heat flow rate due to internal heat sources and Φ_{sol} represents the heat flow rate due to solar heat sources.

The reason of lower annual cooling demand results is while BEP-tr analyses the effects of internal gains, it does not consider the difference of radiative and convective gains and uses eq. 3.2 as a simplification. As in the eq. 3.2, 50 % of the internal gains are instantaneously converted in to room loads applying eq. 3.3.

$$Q^{\circ}_{intheatgain}\,(t) = 0.5 * Q^{\circ}_{intheatload} \qquad \textbf{(3.3)}$$

These assumptions are typical for “standard buildings” where the amount of internal gain is not as high as for example in an Operating Room where it is the prevalent heat load. This type of assumption draws away the results being acceptable for complex buildings which contain a lot of zones that have high internal gain sources.

The third investigation group tries to test possible variation of the coefficient “0.5” in eq. 3.2 that seems to be inappropriate for the distribution of internal heat gains. In particular, it is increased in to “0.7” and new simulations are done by BEP-tr. The results of the third investigation group are shown in Table 3.8 and Figure 3.6. A decrease in Annual Heating Demand results and a significant increase in Annual Cooling Demand results are analysed when the internal gain assumption is changed.

The different results of the first and second investigations affected by the simplification in BEP-tr algorithm become closer to the Energy Plus results when those simplifications are changed in harmony with the dynamic tools, as shown by the third investigations.

Case 7 has the same input data with Case 2. Annual Heating Demand result does not change since there is no infiltration data for this case. Annual Cooling Demand result is higher than Case 2 that is because the effect of internal gains is increased. To obtain a closer result to the detailed simulation method result additional tests have to be performed on this specific topic. Because as expected when the tendency to internal heat gains is increased annual cooling demand would be increased.

Case 8 has the same input data with Case 5. Since the effect of internal gains is increased, Annual Heating Demand results are decreased in compare to Case5 in harmony with the new situation and the result gets closer to Case 4 which is the Energy Plus result. Annual Cooling Demand is increased in comparison to Case 5 as expected and it gets closer to the Energy Plus result in Case 4. This is the effect of increasing the sensitivity to internal gains.

Table 3.8: Third investigations: results for the Operating Room

Operating Room		Unit	Case 7 (E+)	Case 8 (BEP-tr)
Boundary Conditions	Heating set-point	°C	20	20
	Cooling set-point	°C	20	20
	Sensible heat gain from people [16]	W/m^2	4.9	4.9
	Latent heat gain from people [16]	W/m^2	1.6	1.6
	Internal heat gain from lighting	W/m^2	23.7	23.7
	Internal heat gain from equipment	W/m^2	43	43
	Air change rate per hour	1/h	0	3
Annual Energy Demand	Annual Heating Demand	kWh/m^2a	0	0
	Annual Cooling Demand	kWh/m^2a	782	263

The results are shown in diagrams in Figure 3.6. Diagrams show the results of the third investigation group. Comparative results can be seen in Chapter 3.2.1.

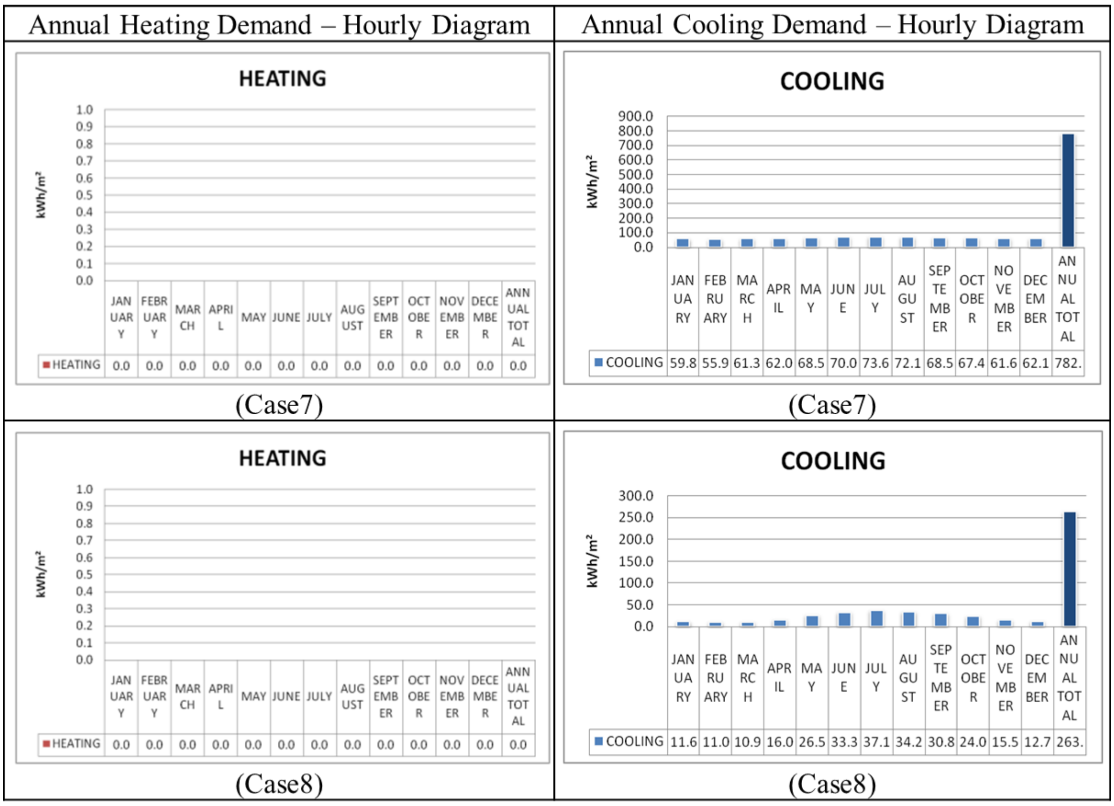


Figure 3.6 : Third investigations: diagram results for the Operating Room

3.2.1 Results

When the weight of internal gain effect on indoor air has been increased, the difference between BEP-tr and Energy Plus changes. The comparison of BEP-tr and Energy Plus results for this case are shown in the figures of 3.7, 3.8, 3.9 and 3.10.

Figure 3.7 shows the comparative results of Energy Plus, BEP-tr and BEP-tr with altered internal gain assumption for the coefficient in eq. 3.2 when the air change rate per hour data is “0 1/h”. It means that the figure shows the comparison between cases 1, 2 and 7 for annual heating demand. All the results are 0 kWh/m²a for BEP-tr and Energy Plus tests. That means the altered internal gain assumption increases heat gain inside of the zone, so a lower annual heating demand value is expected. Since all the results are 0 kWh/m²a, nothing is changed also in the BEP-tr altered coefficient results.

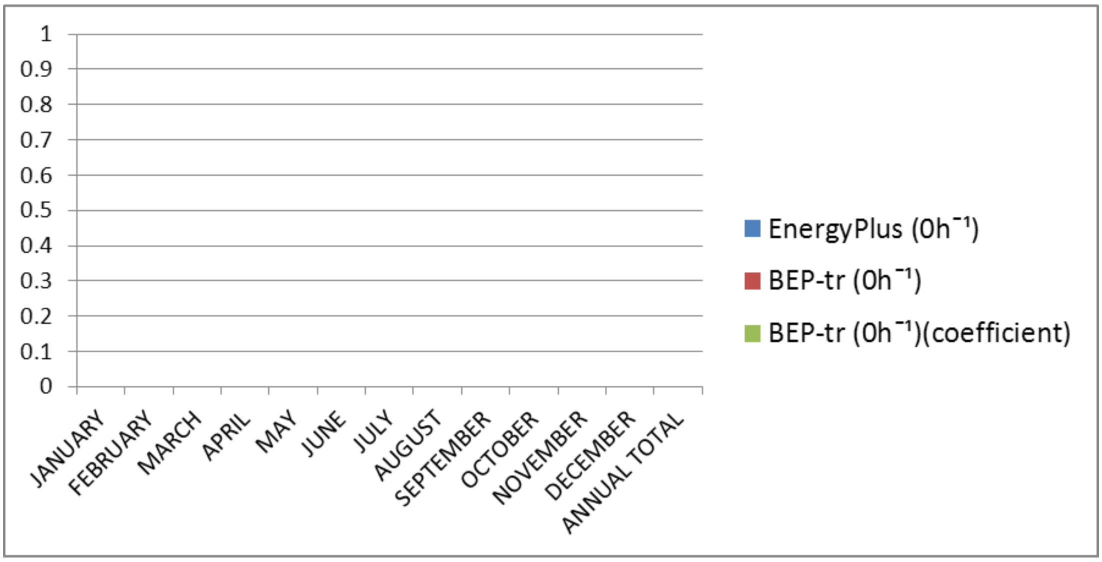


Figure 3.7 : Annual heating demand results comparison for cases 1,2, and 7

Figure 3.8 shows the comparison of cases 1, 2 and 7 for annual cooling demands. Altered coefficient test has been also done in this case just to show the effect of the new condition. (In fact, the main problematic case is when there is a ventilation data.) While the air change rate is “0 1/h” the annual cooling demand result in Energy Plus is 571 kWh/m²a and in BEP-tr it is 702 kWh/m²a. When the internal gain assumption is changed the result becomes 782 kWh/m²a. The annual cooling demand in BEP-tr altered coefficient case is higher than before because the sensitivity to internal gains become more than before, so the internal heat gains have a higher effect than before. For this reason a more cooling need occurred.

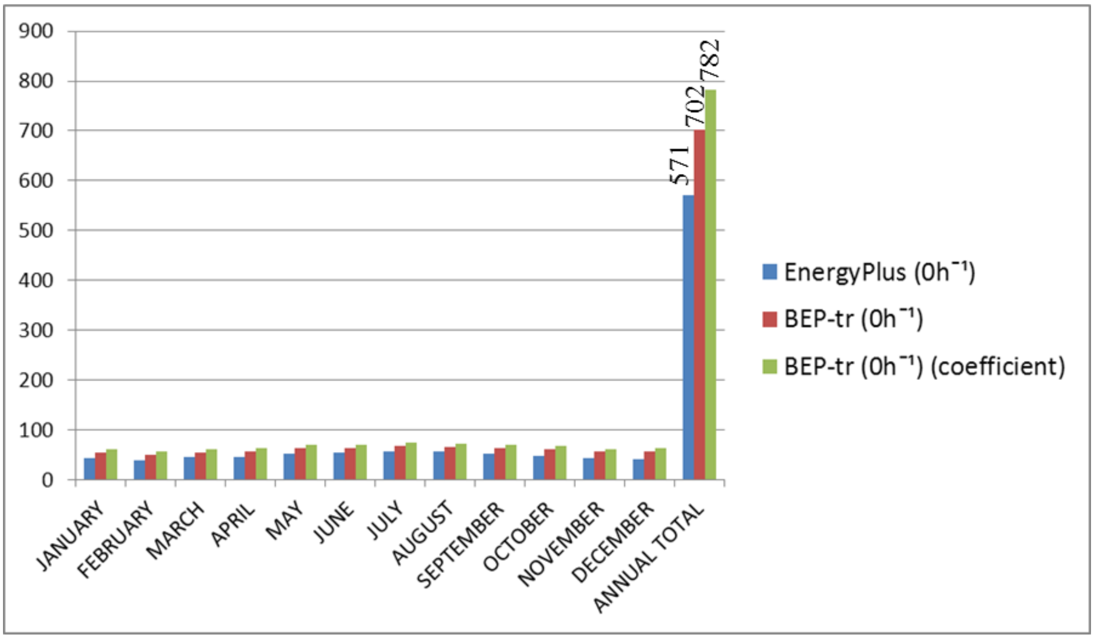


Figure 3.8 : Annual cooling demand results comparison for cases 1,2, and 7

Figure 3.9 shows the comparison in between cases 4, 5 and 8 for annual heating demand results. Since the air change rate is increased from "0 1/h" to "3 1/h" the annual heating demand increased a little as mentioned before. While the Energy Plus result is 0.1 kWh/m²a, the BEP-tr result is 3.3 kWh/m²a for this case. When the internal gain assumption is changed, because of the increased internal gains, the heating demand should have been decreased and as in the figure, BEP-tr coefficient case result is 0 kWh/m²a as expected.

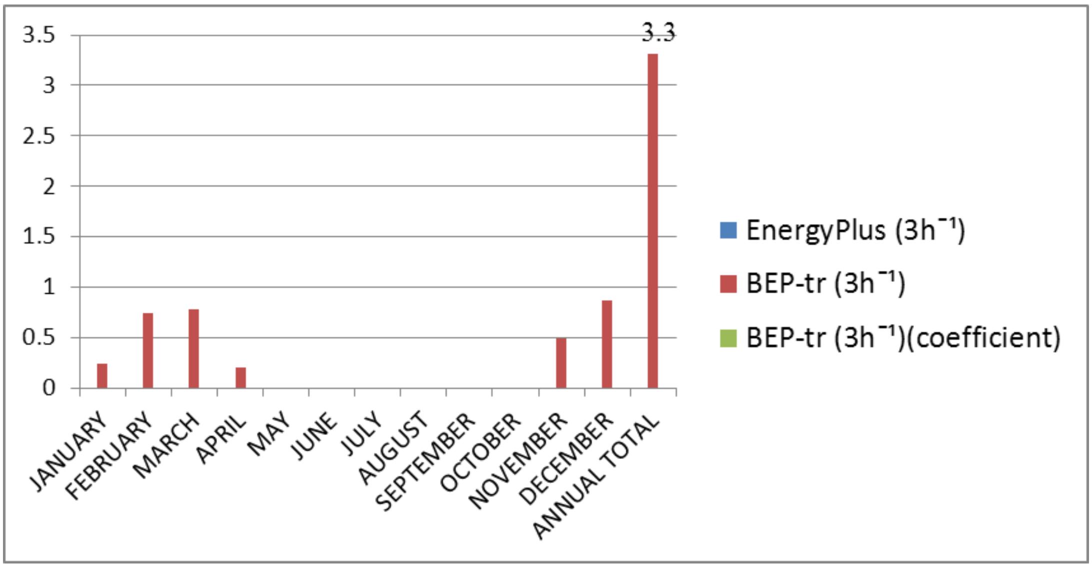


Figure 3.9 : Annual heating demand results comparison for cases 4,5, and 8

Figure 3.10 shows the comparison in between cases 4, 5 and 8 for annual cooling demand results. Because the air change rate per hour data is increased from "0 1/h" to “3 1/h” the annual cooling demand is decreased as mentioned before. While Energy Plus result is decreased from 571 kWh/m²a to 387 kWh/m²a, BEP-tr result is decreased sharply from 702 kWh/m²a to 173 kWh/m²a. When the internal gain assumption is changed, the annual cooling demand result in BEP-tr has become 263 kWh/m²a. Since the effect of internal gains is increased more cooling demand has occurred.

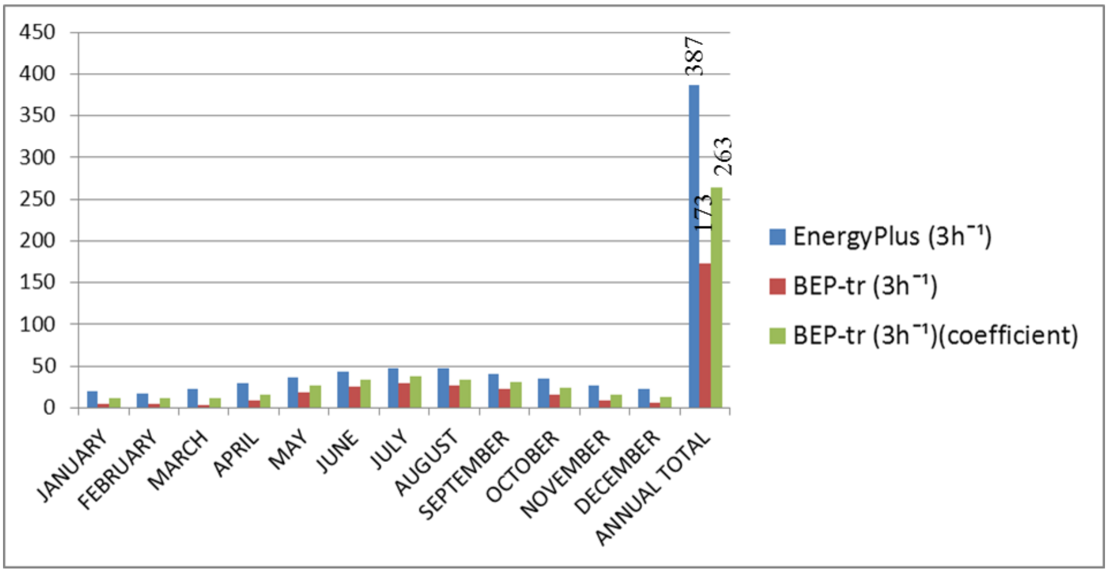


Figure 3.10 : Annual cooling demand results comparison for cases 4, 5, and 8

As in the eq. 3.2, 50% of the heat loads are going to the air and 50% of them are going to the mass. Therefore, the effect of the thermal mass is taken into calculation not dynamically but simplified, so this condition causes the problem. These tests are not the final tests on this subject. The coefficient “0.5” is changed to another value just to test if it will have an effect on the results. There should be more tests specifically on this subject but it should be another specific research headline.

This Chapter of the study is for analysing the default input values of Energy Plus because as mentioned before BEP-tr uses EN standards as reference for hospital buildings. Moreover, the input data that are used in this part was not the main problem, the main aim was to show the differences in between both methods in the terms of boundary conditions and calculation methodologies. However, if EN standards are not enough to continue to the research it is obligatory to find real heat gain values for hospital buildings to figure out the realistic annual heating and cooling demand. After a number of researches it is found that ASHRAE standards have the boundary condition input data for hospital buildings. ASHRAE Handbook

2005 F30 SI also implies that the data are presented in the standard provide guidance in only the most general sense. For large equipment, such as MRI, heat gain must be obtained from the manufacturer.

4. COMPARISON BETWEEN DYNAMIC AND SIMPLIFIED SIMULATION METHODS THROUGH AN EXISTING PROJECT

In this chapter, the study has been carried out for a case study building to compare Energy Plus and BEP-tr with input values from ASHRAE standards and data obtained from manufacturers a new case has been done. In this case, an existing hospital project has been studied and realistic input data is used in the tests.

The project in Figure 4.1 is the ground floor of IVF (In Vitro Fertilization) Center Project that existed in Kosovo. The architect of the project is a Turkish who owned Oğuz Bayazıt Müh. İnş. San. Ltd. Şti. Energy performance tests of the project have been done in Istanbul climate to be able to compare and continue the researches in Chapter 3.

Figure 4.1 : Case study building: IVF Center Project

The ground floor of the project is analyzed to investigate actual boundary condition data and the amount of heating and cooling demands difference among different zones in a real hospital. All of the zones are tested, but two selected zones will be shown in here. Two aims are followed in this case study.

First aim is to compare Energy Plus and BEP-tr energy performance calculation methods in an existed project case with same boundary condition data. The colored zones as in Figure 4.1 are tested to this aim. The colored zones are respectively red colored is the Delivery Room and the blue colored is the Patient Room 5.

Second aim is to reveal how to obtain the input data of a hospital project and how each zone in a hospital has different input data.

In hospitals, natural ventilation is not allowed for some specific sterilized zones as operating rooms, intensive care units, etc. (Turkish Republic Ministry of Health, 2006). In that project, this type of zones faces North direction: on the North façade no transparent component is present.

For all analyzed zones in this case study project, the required air change rate per hour data are obtained from ASHRAE 90412.

4.1 Comparison Between Detailed and Simplified Methods by IVF Center Project

4.1.1 Delivery room

Delivery Room shown in Figure 4.2 is one of the operation areas in the IVF Center. It requires a sterilized area, for this reason there is no transparent component on Delivery Room envelope. The zone also requires specifically sterilized mechanical ventilation.

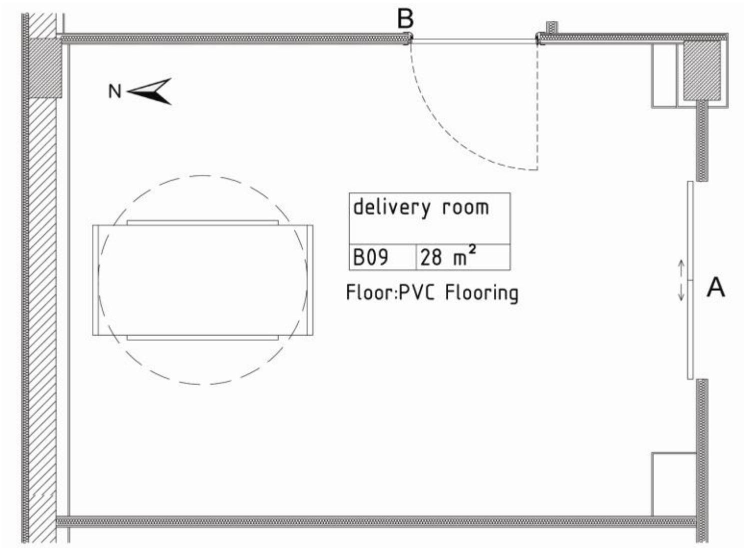


Figure 4.2 : IVF Center: Delivery Room zone

The dimensions of the analyzed Delivery Room are as follows:

A= 4.5 m

B= 6.2 m

Ceiling height= 4 m

Zone area= 28 m^2

Zone volume= 112 m^3

As mentioned before EN standards don't have enough information for hospital buildings' input data, for this reason after a number of researches, ASHRAE standards are used to obtain actual boundary condition values. In Delivery Room case, 'Dimensions and Heat Dissipations of Major Items in Operating Room' of ASHRAE 90412 is used as reference for internal heat gain data.

Boundary condition data that used for Delivery Room zone and annual heating and cooling demands results are shown in Table 4.1. Internal gains due to occupancy, lighting, and equipment are analyzed step by step.

Table 4.1: Results for Delivery Room

Delivery Room		Unit	Energy Plus	BEP-tr
Boundary Conditions	Heating set-point	°C	20	20
	Cooling set-point	°C	23.9	23.9
	Heat gain from people	W/m^2	32.2	32.2
	Internal heat gain from lighting	W/m^2	36.5	36.5
	Internal heat gain from equipment	W/m^2	35.5	35.5
	Air change rate per hour	1/h	5	5
Annual Energy Demand	Annual Heating Demand	kWh/m^2a	3	98
	Annual Cooling Demand	kWh/m^2a	273	0.5

In a Delivery Room, the staff consists of 5 people chief surgeon, assistant surgeon, anesthesiologist, circulating nurse, and scrub nurse. Patient has the least metabolic rate during the operation, for this reason the metabolic rate of the staff is considered for heat gain value from people [18].

In an operation area as Delivery Room, surgical lights and overhead lights should be existed for sufficient lighting and sensitive work [18].

In the zone, there are anesthesia machine, monitors, electrosurgery, vacuum-suction, and HEPA-filter as medical equipment. HEPA-filters are for sterilized ventilation in an operation area which is an absolute filter, high efficiency particulate air filter.

Results are shown in diagrams in Figure 4.3.

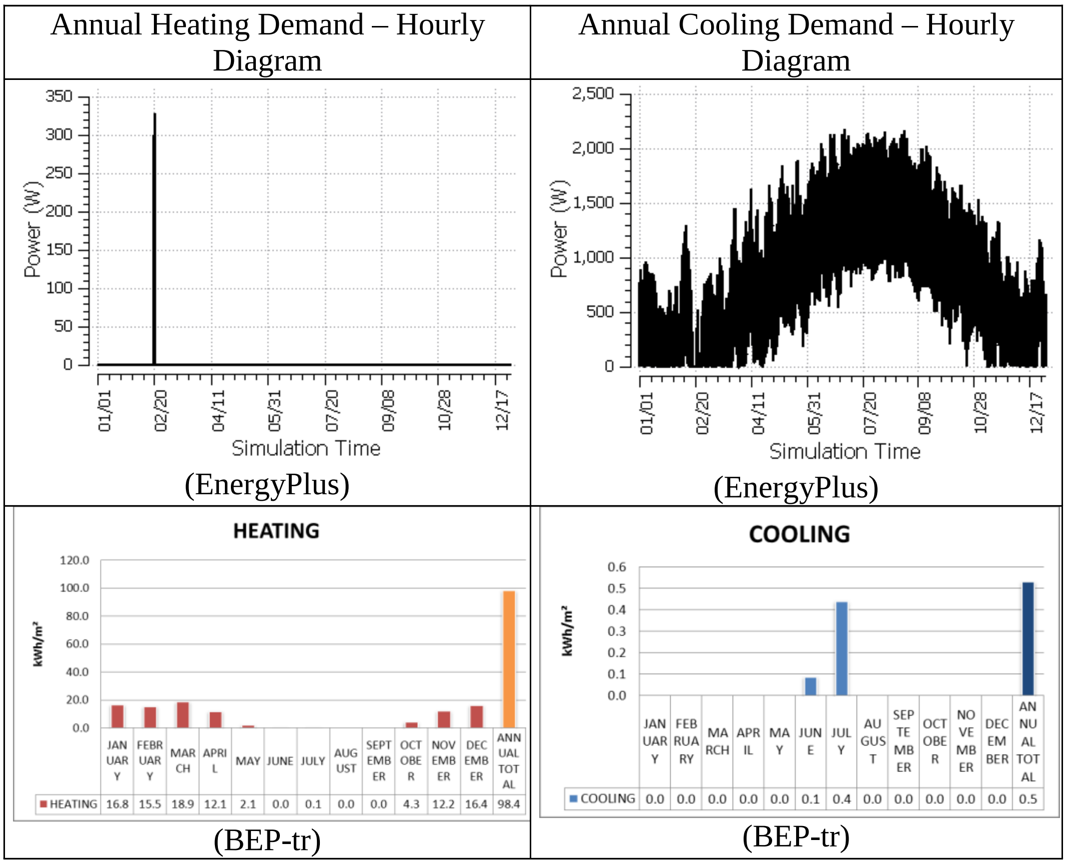


Figure 4.3 : Diagram results for Delivery Room

4.1.2 Patient Room 5

Patient rooms are normally semi-private (two patients) or private (individual patient) and these rooms don't take place in the sterilized area of the healthcare buildings. The main aim of these zones is patient comfort. To this aim, the environment of the room is very important and it requires daylight and natural ventilation for patient comfort and fast recovery. It requires transparent and openable components on the envelope and it does not require hygienic mechanical ventilation. Also, the medical equipment and lighting in this zone are not specific, equipments are usually for examination and emergency. Patient Room 5 is shown in Figure 4.4.

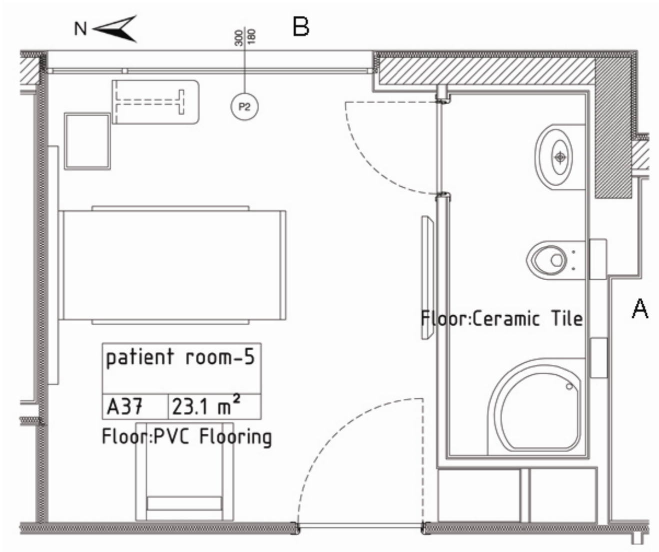


Figure 4.4 : IVF Center: Patient Room 5 zone

The dimensions of the analyzed Patient Room 5 are as follows:

A= 4.5 m

B= 5.2 m

Ceiling height= 4 m

Zone area= 23.1 m^2

Zone volume= 92.4 m^3

In this case study, Patient Room 5 zone is a single patient room. In this case, the occupancy consists of one patient and one guest, and intermittently coming nurse.

Patient Room requires various lighting types according to the comfort of the patient and the examination times. These consist of general lighting, reading lighting, examination lighting, and night light. The specified lighting data do not exist in ASHRAE standards. In this case, the lighting data used in the tests are obtained from medical lighting manufacturers.

In the analyzed zone, there are vacuum suction and central oxygen tubes as medical equipment. Heat gain data from these equipments are obtained from ASHRAE standards [18].

Patient Room requires central heating and air conditioning and, also possible natural ventilation. In this case study example, natural ventilation is provided from East façade of the zone which presents the mixed ventilation condition in patient rooms.

Boundary condition data that used in tests for Patient Room 5 zone and the annual heating and cooling demand results are shown in Table 4.2. Results are also shown in diagrams in Figure 4.5.

Table 4.2: Results for Patient Room 5

Patient Room 5		Unit	Energy Plus	BEP-tr
Boundary Conditions	Heating set-point	°C	21	21
	Cooling set-point	°C	24	24
	Heat gain from people	W/m^2	7	7
	Internal heat gain from lighting	W/m^2	11	11
	Internal heat gain from equipment	W/m^2	25.2	25.2
	Air change rate per hour	1/h	2	2
Annual Energy Demand	Annual Heating Demand	kWh/m^{2}a	6	50
	Annual Cooling Demand	kWh/m^{2}a	119	33

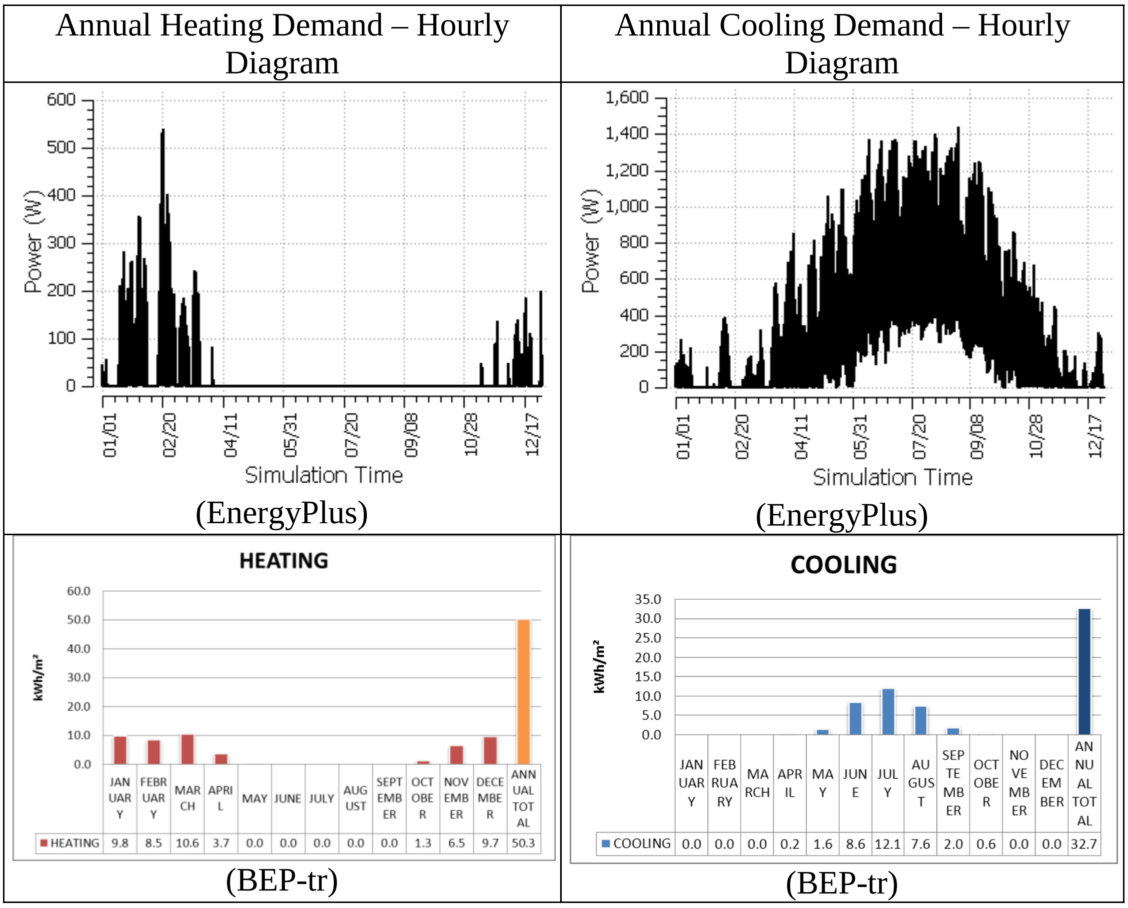


Figure 4.5 : Diagram results for Patient Room 5

4.2 Results

In this phase of study, Delivery Room and Patient Room zones of existing hospital sample are examined. Each zone has different work and activity types, internal environmental quality conditions, and thermal balances. The first aim of this study is to compare Energy Plus and BEP-tr calculation methods as mentioned before.

In the Delivery Room zone the air change rate per hour data is “5 1/h” according to the ASHRAE 90412. As explained in Chapter 3, BEP-tr method has more sensitivity to the ventilation coefficient than to internal gains. For this reason, while Energy Plus results are 3 kWh/m²a for annual heating demand and 273 kWh/m²a for annual cooling demand, BEP-tr results are 98 kWh/m²a for annual heating demand and 0.5 kWh/m²a for annual cooling demand. Since Delivery Room is an operation area internal gain rate from medical equipment and lighting is very high as shown in Table 4.1. For this reason, even with the high air change rate value, low heating and high cooling demand is expected as Energy Plus results. However, because of the simplification in the algorithm of BEP-tr that mentioned in Chapter 3, BEP-tr tends to underestimate the cooling loads and overestimate the heating loads especially when there is a high air change rate.

In the Patient Room, the air change rate per hour data is again “2 1/h” according to the ASHRAE 90412. Internal gains are lower than the other zones in Patient Room. This zone has a normal internal gain rate. Energy Plus results are 6 kWh/m²a for annual heating demand and 119 kWh/m²a for annual cooling demand. BEP-tr results are 50 kWh/m²a for annual heating demand and 33 kWh/m²a for annual cooling demand. In this case, since the air change rate is a normal value, for BEP-tr tests the reason of the different results is the simplification in BEP-tr algorithm for internal gains. In this case, BEP-tr has a tendency for both heating and cooling however, because of the simplification; the heating demand is higher than the cooling demand.

5. ANALYZING THE RESULTS OF THE DYNAMIC SIMULATION TOOL BASING ON THE BOUNDARY CONDITION OF AN EXISTING HOSPITAL BUILDING

5.1 Analysis of The Case Study

The main aim of this thesis is to find an appropriate method to be able to simulate the healthcare buildings and proper sources to have complete boundary condition data for energy performance calculations. This phase of the study is an example to show the condition of existing hospitals with their measured heat gains through CTO Torino, Italy.

CTO is one of the oldest hospitals in Torino, Italy. Because it is an old hospital, the building envelope materials are not in a good condition like the new modern hospitals. However, it is a good example to show the energy performance of most of the hospitals. This project is studied with an energy manager who measures the heat gains from the equipments by energy monitoring. The energy manager provides the heat gain data from equipments, number of people in each zone, architectural plans and building envelope materials, lighting plans, and working hour schedules. Energy simulator who obtains these data from the energy manager makes the model of the building and simulates the building by using provided input data. The energy performance tests have been done in Torino climate.

In Figure 5.1 the fourth floor plan of CTO Torino is shown. The floor on East side is Patient Ward and the floor on West side is the Operating Floor and they connect each other with a bridge. In the previous studies, each thermal zone analyzed separately, because those analysis were to compare Energy Plus and BEP-tr calculation methods.

In this phase of study, since it is to show the energy performance condition of a hospital building, whole floor is simulated at the same time. For this reason, Energy Plus as an integrated simulation tool is used to investigate the energy performance rate of a Patient Ward floor and an Operating floor.

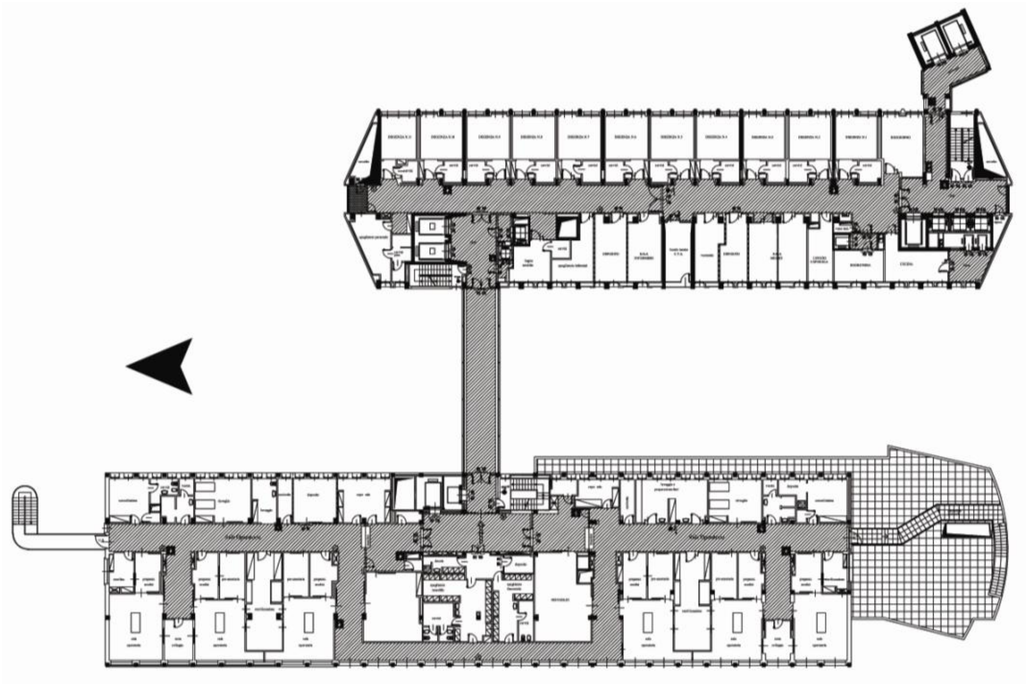


Figure 5.1 : CTO: 4th floor architectural plan

The building includes 4 Operating Floors same with the example one in Figure 5.1 and 14 Patient Ward floors same with the example one in Figure 5.1.

There are 30 zones in Patient Ward Floor as shown in Figure 5.2 and it includes doctor, nurse and staff areas and 11 patient rooms. To be able to analyze energy performance of whole floor each thermal zone should be defined separately in Energy Plus. Energy Plus simulates all of the zones at the same time.

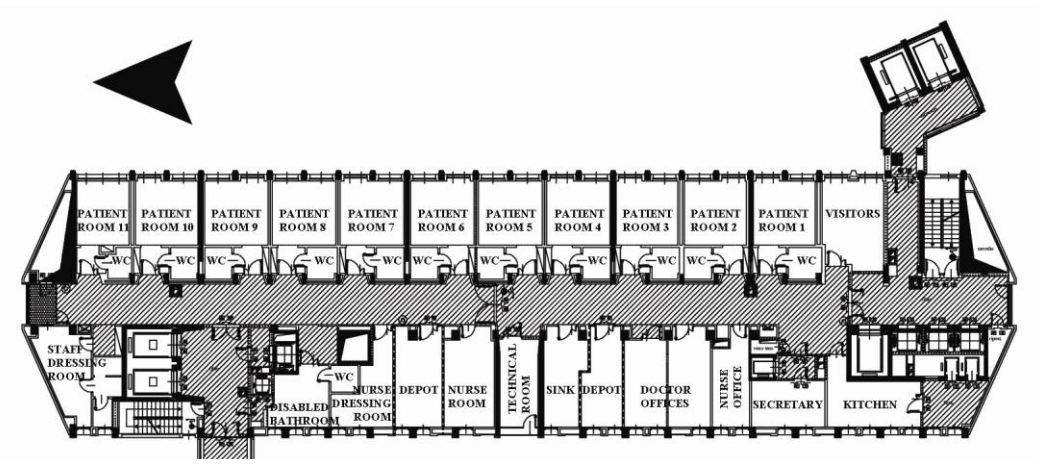


Figure 5.2 : CTO: 4th floor Patient Ward plan

The tests in Chapters 3 and 4 were in Istanbul climate which is hotter than Torino climate. Torino is in the E zone according to the Italian standard with the cold climatic zone. For this reason, in this phase of study, it was expected that heating demand would be more than cooling demand. In addition, since it is an old hospital, the building envelope components are not enough to block the outdoor climate effect.

Table 5.1 shows the annual heating and cooling demand results for each zone in Patient Ward floor and at the end of the table, annual heating and cooling demand results for the whole floor are shown.

Table 5.1: Annual heating and cooling demand for each zone in Patient Ward floor and whole Patient Ward floor

Room	Annual Heating Demand (kWh/m^{2}a)	Annual Cooling Demand (kWh/m^{2}a)	Area
Staff Dressing Room	199	27	25
Staff Bathroom	145	37	15.8
Entrance 1	135	37	85.8
Disabled Bathroom	173	34	24
Nurse Bathroom	166	21	33.5
Depot 1	151	24	25.8
Nurse Room	0	77	27.5
Technical Room	156	33	23
Sink	169	18	23.4
Depot 2	173	25	20.6
Doctor Room 1	163	27	23.3
Doctor Room 2	159	22	23.1
Nurse Office	147	39	20.3
Technical Space	152	11	13.4
Secretary	147	53	19.7
Kitchen	170	47	27.4
Entrance 2	150	33	147.2
Visitor Room	150	45	33.4
Patient Room 1	144	41	35.5
Patient Room 2	144	41	35.5
Patient Room 3	144	41	35.5
Patient Room 4	144	41	35.5
Patient Room 5	145	37	35.5
Patient Room 6	144	41	35.5
Patient Room 7	144	41	35.5
Patient Room 8	145	37	35.5
Patient Room 9	145	41	35.5
Patient Room 10	146	41	35.5
Patient Room 11	165	45	29
Corridor	126	21	159.5
TOTAL	**144**	**35**	**1155.7**

The internal heat gains from equipment, lighting and occupancy are provided from the energy manager. Heat gain from medical equipments is measured by the energy manager through monitoring, lighting plans are gathered with the architectural plans for building envelope materials by energy manager and occupancy is provided from hospital management. Through lighting plans, heat gain from lighting is calculated according to the given lighting system equipments for each zone. Building envelope materials, especially for walls, are found in detail from the architectural plans and, also sections are used to measure the floor height and to gather the information for floor and ceiling components. After gathering all these data, the air change rate per hour is used according to the Italian standards, and it is required “2 1/h” for whole Patient Ward floor [19] [20].

In this floor, there is not a lot of medical equipments; only a few appliances exist in Patient Rooms. Usually, in branch type hospitals there are various equipments in patient rooms; however, since those rooms are general patient rooms in this example hospital building, there are only appliances for emergency. In the offices, there are computers as electrical equipments. The number of computers differs from one room to another according to the staff number inside.

The most important reason that the annual heating demand is more than the annual cooling demand is weak building envelope and cold Torino climate. Since it is an old building, envelope materials are not enough to resist the effects of cold climate.

There are 40 zones in Operating Floor as in Figure 5.3; it includes operating and consultation areas. As in the Patient Ward case, to be able to analyze energy performance of whole floor, each thermal zone should be defined separately in Energy Plus and it simulates all of the zones at the same time.

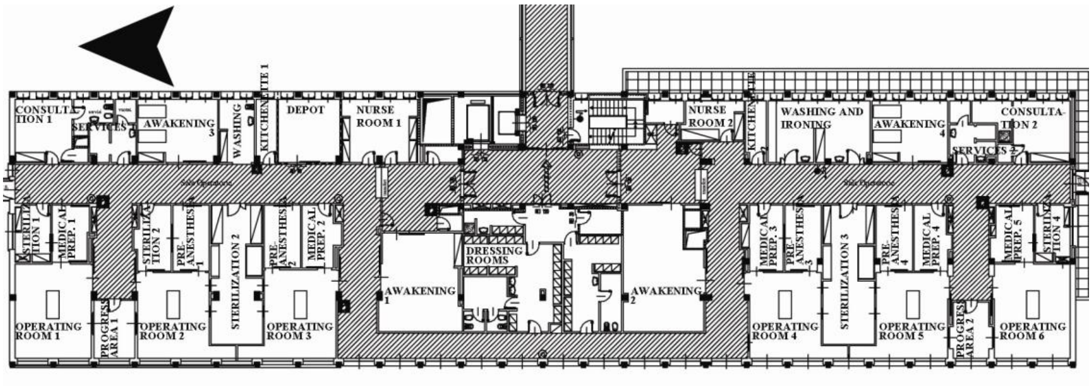


Figure 5.3 : CTO: 4th floor Operating Floor plan

Table 5.2 shows the annual heating and cooling demands results for each zone in the Operating Floor and at the end of the table, annual heating and cooling demands for the whole floor are shown.

Table 5.2: Annual heating and cooling demand for each zone in Operating Floor and for whole Operating Floor

Room	Annual Heating Demand (kWh/m^{2}a)	Annual Cooling Demand (kWh/m^{2}a)	Area
Operating Room 1	1082	115	45
Sterilization 1	140	154	12.3
Medical Prep. 1	327	26	12.8
Progress Area 1	361	55	15
Operating Room 2	1014	135	40
Medical Prep. 2	337	22	12.5
Pre-Anesthesia 1	319	24	13.4
Sterilization 2	161	99	37.8
Operating Room 3	1015	133	40
Pre-Anesthesia 2	319	24	13.4
Medical Prep. 3	337	22	12.5
Awakening 1	382	12	44.7
Dressing Rooms	193	5	107.2
Awakening 2	386	11	55
Consultation 1	232	36	23.3
Services 1	211	31	23.7
Awakening 3	402	32	30.4
Washing	201	38	13.7
Kitchenette 1	207	37	8.3
Depot	211	29	24
Nurse Room 1	168	56	28.3
Entrance	200	11	179.8
Nurse Room 2	174	71	15.5
Kitchentte 2	200	41	8.3
Washing and Ironing	202	32	38.7
Awakening 4	396	35	29.5
Services	407	31	23.7
Consultation 2	36	60	23.3
Operating Room 4	1015	133	40
Medical Prep. 4	337	22	12.5
Pre-Anesthesia 3	319	24	13.4
Sterilization 3	161	99	37.8
Operating Room 5	1014	134	40
Progress Area 2	359	55	15
Pre-Anesthesia 4	319	24	13.4
Medical Prep. 5	337	22	12.5
Operating Room 6	1069	119	45
Medical Prep. 6	323	26	12.8
Sterilization 4	124	171	12.3
Corridor	181	23	320
TOTAL	**366**	**47**	**1506.8**

In Chapters 3 and 4, Operating Room zones are tested alone and the effect of the other thermal zones on operating room zone is ignored.

In this phase of study, there are 6 operating rooms and these zones are tested at the same time with the other thermal zones in the floor.

The internal heat gains from equipment, lighting and occupancy are provided from the energy manager. Heat gain from medical equipments is measured by the energy manager, lighting plans are gathered with the architectural plans for building envelope materials by energy manager and occupancy is provided from hospital management. After gathering all these data, the air change rate per hour is used according to the Italian standards, and it is required “15 1/h” for Operating Rooms, “4 1/h” for the zones around the operating rooms, and “2 1/h” for the other thermal zones [19] [20].

In the previous investigations, the operating room always has more cooling demand than the heating demand. In this phase, the results are the opposite because of the Italian standard, air change rate value is “15 1/h” and it is a really high value for infiltration. However, because the Italian Standard forces to use this value, the tests have been done with the required data. In addition, the annual heating demand is more than the annual cooling demand for the whole floor. The reason of this result is the same with the Patient Ward case that the weak building envelope and the cold Torino climate.

Briefly, Torino is a cold Italian city in E Italian climatic zone and the building has both low energy performances of the envelope and high ventilation rate (15 h^{-1}): as a consequence, the energy demand for space heating is always sensibly higher than the energy demand for space cooling.

5.2 Effect of The Variability of Boundary Conditions on Heating and Cooling Demand

When we face a real hospital building case how in reality, we would have variation in comparison to standard situation. Also, boundary condition data change from one hospital to another. Each healthcare building could be a different case study and it is hard to generalize them and the required data for them.

Before starting to analysis, it is crucial to explain that what branch hospital means. Healthcare facilities range widely in the nature and complexity of services they provide and in the relative degree of illness or injury of the patients treated – from a neighborhood general practitioner’s office to large regional or university medical centers and specialty hospitals. Basically, a hospital is an institution for treating and caring for four or more persons who need medical attention 24 hours a day, every day. Hospitals can be classified in three ways: by length of stay, by the diseases of its patients, and by the type of ownership [18].

Short-term hospitals are those where patients stay less than 30 days. Specialty hospitals, such as cancer centers, centers for women and children, or mental health centers, define themselves by the type of services provided. Ownership can be of three types; community owned, proprietary, government owned [16].

Energy demand of each type of hospital differs according to their activity type. Generally, it is not possible to have different type of branch hospitals with the same energy demand. The units in each hospital will have different occupancy and activity types and these units determine the energy need of the hospitals.

According to ASHRAE 90412, these mentioned units can be basically; patient care units, diagnostic and treatment centers, surgery suites, administrative areas, support services. These are the headlines of the units, each of them will have different rooms according to the branch type of the hospital.

IVF Center project from Chapter 4 and CTO Torino in this chapter are analysed to show the possible variation of required input data. From IVF Center selected Delivery Room, Patient Room, and Consultation Room zones as in Figure 5.4 and from CTO Torino selected Operating Room, Patient Room, and Consultation Room zones as in Figure 5.5 are all tested in Istanbul climate. Similar zones from different hospital building projects are chosen and tested in the same climatic zone to be able to compare behaviours of the zones.

In the IVF Center tests, ASHRAE standard values are used for the boundary condition data for each zone. So, IVF Center case can be considered as a standard required hospital case. In CTO Torino case, monitored data are used as boundary condition data, so it can be considered as current condition hospital case. Therefore, it could be possible to test hospital buildings with required boundary condition data through standards and with current condition data through monitoring to be able to show the variability of input data and their effects on results. To this aim, as mentioned before, similar zones are used from both projects.

Figure 5.4 : Selected zones from the IVF Center

Figure 5.5 : Selected zones from CTO Torino

Delivery Room zone in IVF Center as explained in Chapter 4 is an operating room. So, it is examined together with the Operating Room zone in CTO Torino. Energy Plus energy performance assessment results for IVF Center Delivery Room zone is shown in Table 5.3 and results for CTO Torino Operating Room zone are shown in Table 5.4.

Table 5.3: Delivery Room boundary condition data – IVF Center

		Values	Unit
Boundary Conditions	Heating set-point	20	°C
	Cooling set-point	24	°C
	Heat gain from people	18	W/m^2
	Internal heat gain from lighting	36.5	W/m^2
	Internal heat gain from equipment	35.4	W/m^2
(28 m^2)	Air change rate per hour	5	1/h
Annual Energy Demand	Annual Heating Demand	3	kWh/m^{2}a
	Annual Cooling Demand	273	kWh/m^{2}a

Table 5.4: Operating Room boundary condition data – CTO Torino

		Values	Unit
Boundary Conditions	Heating set-point	20	°C
	Cooling set-point	24	°C
Monitoring	Heat gain from people	11	W/m^2
	Internal heat gain from lighting	15.3	W/m^2
(45 m^2)	Internal heat gain from equipment	59.5	W/m^2
	Air change rate per hour	15	1/h
Annual Energy Demand	Annual Heating Demand	823	kWh/m^{2}a
	Annual Cooling Demand	170	kWh/m^{2}a

Since Delivery Room and Operating Room zones are both operating areas, similar boundary condition data are expected. Both operating areas have the same temperature set-point values. Internal heat gain from people is also same when the unit is in Watt. However, in IVF Center internal gain values from lighting and equipment are from ASHRAE standards. In the case of CTO Torino, these values are the results of monitoring. Therefore, the standard values and real values have a difference in between and this condition affects the results. In addition, some of the values, especially ventilation values, change according to the country that the building takes place. As in this example, ASHRAE standards require “5 1/h” air change rate per hour value for operating rooms, however since CTO Torino takes place in Italy, Italian standards applied on Operating Room zone and these standards require “15 1/h” for operating rooms. It is possible to say that ventilation is highly related to national standards and it cannot be generalized. So, the air change rate per hour value depends on the location of the building.

In this case, the annual heating and cooling demand results for both operating areas are different because of the variation in the boundary condition data. Since there is a huge internal gain from medical equipments and a high air change per hour value in the Operating Room of CTO Torino, it requires a bigger boiler and a smaller chiller than the Delivery Room in IVF Center.

Energy Plus energy performance assessment results of IVF Center and CTO Torino Patient Room zones are shown respectively in Table 5.5 and Table 5.6.

Table 5.5: Patient Room boundary condition data – IVF Center

		Values	Unit
Boundary Conditions	Heating set-point	21	°C
	Cooling set-point	24	°C
	Heat gain from people	7	W/m^2
	Internal heat gain from lighting	10.6	W/m^2
	Internal heat gain from equipment	25.2	W/m^2
(23.1 m^2)	Air change rate per hour	2	1/h
Annual Energy Demand	Annual Heating Demand	6	kWh/m^{2}a
	Annual Cooling Demand	119	kWh/m^{2}a

Table 5.6: Patient Room boundary condition data – CTO Torino

		Values	Unit
Boundary Conditions	Heating set-point	20	°C
	Cooling set-point	24	°C
Monitoring	Heat gain from people	4.6	W/m^2
	Internal heat gain from lighting	6.7	W/m^2
(35.5 m^2)	Internal heat gain from equipment	5	W/m^2
	Air change rate per hour	2	1/h
Annual Energy Demand	Annual Heating Demand	109	kWh/m^{2}a
	Annual Cooling Demand	57	kWh/m^{2}a

Since both zones are patient rooms, their aim is same and so, similar boundary condition data expected for each zone.

In both patient rooms, heat gain from people have the same value in Watt units. Also, air change rate per hour data are same both in ASHRAE and Italian standards for Patient Rooms. In these zones, the most important difference is on internal heat gain from medical equipments. In the Patient Room zone in IVF Center, this value depends on ASHRAE standards while it depends on monitored data in CTO Torino case. In IVF Center Patient Room, since this room is for women who gave birth and for their babies, there are some other special appliances which increase the internal heat gain value from equipments while CTO Torino Patient Room is a general patient room with almost no medical equipment (only moving/constant oxygen pump).This condition implies that when Patient Room does not mean a constant case and these zones can vary according to the activity or patient type in this zone. So, even the aims of the zones are same, same boundary condition data can not be used, it can not be considered as these zones are both patient rooms so same input data can be used. Because input data can vary for each zone in accordance with the branch type of the hospital.

Therefore, with high internal gain value from medical equipments, Patient Room in IVF Center has less heating demand and more cooling demand than CTO Torino Patient Room example.

Consultation Room means examination room where medical doctors work during the day. In general, the aim of examination rooms is diagnostic and treatment. Energy Plus energy performance assessment results of IVF Center Consultation Room zone and CTO Torino Consultation Room zone are shown respectively in Table 5.7 and Table 5.8.

Table 5.7: Consultation Room boundary condition data – IVF Center

		Values	Unit
Boundary Conditions	Heating set-point	21	°C
	Cooling set-point	24	°C
	Heat gain from people	15	W/m^2
	Internal heat gain from lighting	9.1	W/m^2
	Internal heat gain from equipment	51.4	W/m^2
(25.2 m^2)	Air change rate per hour	2	1/h
Annual Energy Demand	Annual Heating Demand	2	kWh/m^{2}a
	Annual Cooling Demand	238	kWh/m^{2}a

Table 5.8: Consultation Room boundary condition data – IVF Center

		Values	Unit
Boundary Conditions	Heating set-point	21	°C
	Cooling set-point	24	°C
Monitoring	Heat gain from people	16	W/m^2
	Internal heat gain from lighting	9.2	W/m^2
(23.3 m^2)	Internal heat gain from equipment	5.8	W/m^2
	Air change rate per hour	2	1/h
Annual Energy Demand	Annual Heating Demand	184	kWh/m^{2}a
	Annual Cooling Demand	51	kWh/m^{2}a

In both consultation rooms, except heat gain from medical equipments, all other data are almost same. That is because, the meaning of examination changes according to branch type of the hospital. The Consultation Room in CTO Torino is a general consultation room for usual patients and it only includes a computer as an electrical equipment to register the condition of patients, however the Consultation Room in IVF Center is for pregnant women and it includes an ultrasound system and hysteroscopy pump in addition to the computer. For this reason, internal heat gain from equipments cannot be same in these zones; even the aim of the zones is same. The equipments have different electrical and thermal power and according to the sort of power that put in a room, different internal gains would be obtained. Therefore, the IVF Consultation Room requires less heating demand and more cooling demand than the CTO Consultation Room in accordance with the high internal heat gain value from medical equipments.

In addition to the differences in between boundary condition data, the differences in between building envelope components have an important effect on results. IVF Center is a modern building with modern building components shown in Table 5.9.

Table 5.9: Opaque building components for IVF Center case zones

Layer Name	Material	Thickness (d)-m	Conductivity (λ)-W/m-K
External Wall Layers	1 IN Stucco	0.012	0.7
	Mass NonRes Wall Ins	0.05	0.05
	Brick	0.25	0.9
	Wall air space		
	½ IN Gypsum	0.0125	0.16
Internal Wall Layers	½ IN Gypsum	0.0125	0.16
	Insulation: Cellular glass	0.075	0.05
	½ IN Gypsum	0.0125	0.16
Floor Layers	HW Concrete	0.3	1.3
	Grout	0.09	1.4
	Self Leveling	0.004	0.2
	PVC	0.006	0.17
Ceiling Layers	Marble	0.006	3.2
	Self Leveling	0.004	0.2
	Grout	0.09	1.4
	HW Concrete	0.13	1.3
	Ceiling air space		
	½ IN Gypsum	0.0125	0.16
	½ IN Gypsum	0.0125	0.16

CTO Torino is an old hospital building with old building components that shown in Table 5.10. It has been built around 1963-1970 and since then, there were no renovation. Therefore, all of the building components are old and are not appropriate to the standards of today.

Table 5.10: Opaque building components for CTO Torino case zones

Layer Name	Material	Thickness (d)-m	Conductivity (λ)-W/m-K
External Wall Layers	Cement and Sand	0.02	1
	Hollow Brick	0.08	0.4
	Horizontal air gap flux		
	Lightweight hollow concrete block	0.245	0.5
	Gypsum plaster	0.02	0.57
Internal Wall Layers	Lime	0.02	1.14
	Hollow Brick	0.1	0.4
	Lime	0.02	0.57
Floor Layers	Concrete made by natural aggregates	0.02	0.33
	Block slab tile	0.18	1.11
	Expanded clay concrete	0.07	0.5
	Cement mortar	0.02	0.65
	Ceramic	0.01	1.6
Ceiling Layers	Ceramic	0.01	1.6
	Cement mortar	0.02	0.65
	Expanded clay concrete	0.07	0.5
	Block slab tile	0.18	1.11
	Concrete made by natural aggragates	0.02	0.33

The difference in between building components is obvious in Table 5.11. The weak components that CTO have affect the heat gain/loss through building envelope in a negative way while the modern components of IVF Center have a better resistance.

Table 5.11: U values for IVF Center and CTO Torino case zones

Layer Name	(IVF) U factor – W/m^{2}K	(CTO) U factor – W/m^{2}K
External Wall	0.65	2.2
Internal Wall	0.54	2.2
Floor	1.2	1.77
Ceiling	2	1.77
Window	3.23	5.78

Therefore, the thermal characteristics of the building envelope have also an effect on space heating and cooling demands with the variability of the boundary conditions.

In the comparative results of this chapter CTO zones have more heating and less cooling demand than IVF Center zones, that is because both reasons as mentioned above. However, in a hospital building the most important parameter that influences annual heating and cooling demand is internal heat gains. So, envelope components of course should be considered, but it should be kept in mind that because of the high internal gains, building envelope less effective than internal heat gains on the results.

As a result, space heating and cooling demands are affected by;

- Complexity of the building itself as shape, geometry, function, etc.
- Complexity of indoor environmental requirements in definition of temperature set-point requirements
- Complexity in the definition of boundary conditions about ventilation and internal gains

The investigations should be done not only from the modelling point of view but also it should be clear on envelope, dimensions, and boundary conditions. It should be considered that the definition of what is analyzing in the case of hypothesis and certification.

Energy assessor shouldn’t generalize the boundary condition data of a zone. Because, this zone could have different boundary condition data according to the activity type of the hospital.

6. CONCLUSION AND RECOMMENDATIONS

In this thesis with the headline “Comparative Analysis of Dynamic and Simplified Energy Performance Methods for Hospital Buildings”, the algorithm of Turkish National Building Energy Performance Calculation Methodology BEP-tr is compared to Energy Plus which is a detailed energy performance calculation method. The aim of these comparisons is to suggest a more appropriate calculation method for hospital buildings. To this aim, various cases are examined and for the aim of researches the boundary condition data, calculation algorithm, boundary condition sources are investigated respectively on example case study hospital projects. The Turkish energy performance calculation method for energy certification BEP-tr is a simplified calculation method that has been developed in principle to be used for all building typologies; however, it is more appropriate to use it for residence, education and simple office buildings for now. Since a detailed simulation tool can assess energy performance of a hospital building, to figure out the differences in simplified methodology BEP-tr is compared with Energy Plus.

According to the researches for hospital buildings BEP-tr uses EN standards as reference for boundary condition data. However, EN standards are not enough for hospital buildings and after obtaining this result, ASHRAE standards and manufacturers’ help are used to continue to the examinations for energy performance assessments of hospital buildings.

In a hospital building, as shown in all phases of study there are a lot of thermal zones and each of them has different working, activity, temperature set-point, internal gain, and ventilation schedules. BEP-tr calculates the energy performance of hospital buildings with a simplification that distributes all the parameters of each thermal zone to the whole floor with the area weighted average value. In this case, the different parameters of each thermal zone don’t have an effect on each other. This simplification is normal for energy performance calculations of standard buildings and it is also useful for the usage of the software. However, it is a problem for complex building cases as it is analyzed in this study for hospital buildings.

Usually national energy performance calculation methods like BEP-tr are appropriate to evaluate the energy performances of building typologies with low intensity of internal gains which means their algorithms are appropriate for standard buildings. As in Chapter 3.2 BEP-tr adopts the simplification which is required by EN 13790 for heat gain/loss through transmission and internal gains. This simplification is not a problem for standard buildings with normal internal gain rates. However, for complex buildings heat gain algorithms should be in harmony with the detailed simulation algorithms to distribute the heat gains with appropriate coefficients as radiative and convective.

After investigating the shortcomings in the database and algorithm of BEP-tr, to show the effects of sufficiency of the parameters on energy performance assessments an existing IVF Center project is tested in Chapter 4 by using ASHRAE standards and manufacturer help. With appropriate boundary condition data the differences in BEP-tr algorithm in comparison to Energy Plus is discussed and showed again. While BEP-tr is sensetively affected from air change rate Energy Plus calculates energy performance of each zone in all conditions. Therefore, after this part it has become certain that BEP-tr algorithm should be improved with less sensitivity to the ventilation coefficient and more sensitivity to the internal gain rates as enough as in detailed calculation methodologies. In addition to this, in the database of national energy performance calculation method of Turkey different standards than EN standards should be used for hospital buildings. In other case, Turkey should improve its standards for boundary condition data of hospital buildings because, the data for medical equipment and lighting are not sufficient also in ASHRAE standards. In some European countries, these data exist in their Building Energy Performance Acts.

All investigations are done in Istanbul climate since BEP-tr is the Turkish national energy performance calculation method. However, to examine the current condition of hospital buildings the research with an energy manager from Politecnico di Torino has been done for CTO Torino which is an old building. After all analysis it is obvious that to analyze a hospital building it would be easier to use Energy Plus since BEP-tr need to be improved for complex buildings. Torino is in the E Italian climatic zone with a cold climate zone in compare to Istanbul. In all other cases with modern building envelope and a hotter climate the annual heating demand is always higher than the annual cooling demand because of the high internal gain rates. Even with high internal gains because of the climatic zone and the weak building envelope the annual heating demand is higher than the annual cooling demand in example CTO Torino case. Moreover, in the other cases thermal zones are investigated separately and the zones in the sterilized area with specific activity types need more cooling, but in this phase all of the thermal zones in one floor are simulated together. For this reason, the presented results are for the whole floor. In addition to all of these, for the Operating Floor, the high air change rate (15 h^{-1}) makes the difference with high annual heating demand results for the operating rooms.

After all, it could be able to show the effects of variation on boundary conditions on annual heating and cooling demand results by required boundary condition data through standards and current condition data through monitoring. In this case, IVF Center respresents a standard case hospital building and CTO Torino represents a real monitored case hospital building. Since, similar zones are tested in Energy Plus it is expected to obtain similar results with corresponding boundary condition data. However, the standards require different internal heat gain data than the monitored data especially when it comes to medical equipment. It is highly related to the variation of indoor environmental requirements, functions, schedules and supportingly the boundary condition data according to the branch type of the hospital. According to ASHRAE 90412, healthcare buildings can be classified as short-term hospitals, specialty hospitals, and community or government owned hospitals. In general, except general hospitals, each hospital type also classifies in itself and there are a lot of branch hospitals. When detailed researches are carried out it would be seen that while the energy demand of each zone is different in an hospital building, also it differs according to the hospital typology. Therefore, it is impossible to generalize the boundary condition data for hospitals and, also for the similar zones in different type of hospitals. Moreover, ventilation data depends on the location of the building, so it is not possible to generalize also this value. The quality of the building components and the shape of the building also have impact on the annual heating and cooling demand results. When both buildings are tested in the same climatic zone as in Chapter 5.2, this impact obviously can be seen. Therefore, it is very important to select right values for energy performance assessments to be able obtain realistic results.

In Figure 6.1 it is shown how to obtain boundary condition data for hospital buildings. This diagram shows a method how to obtain right values for hospital energy performance analysis. Since, most of the standards only include data for general hospital zones, detailed research and aslo manufaturer help are needed for branch hospital zones especially for equipment and lighting data.

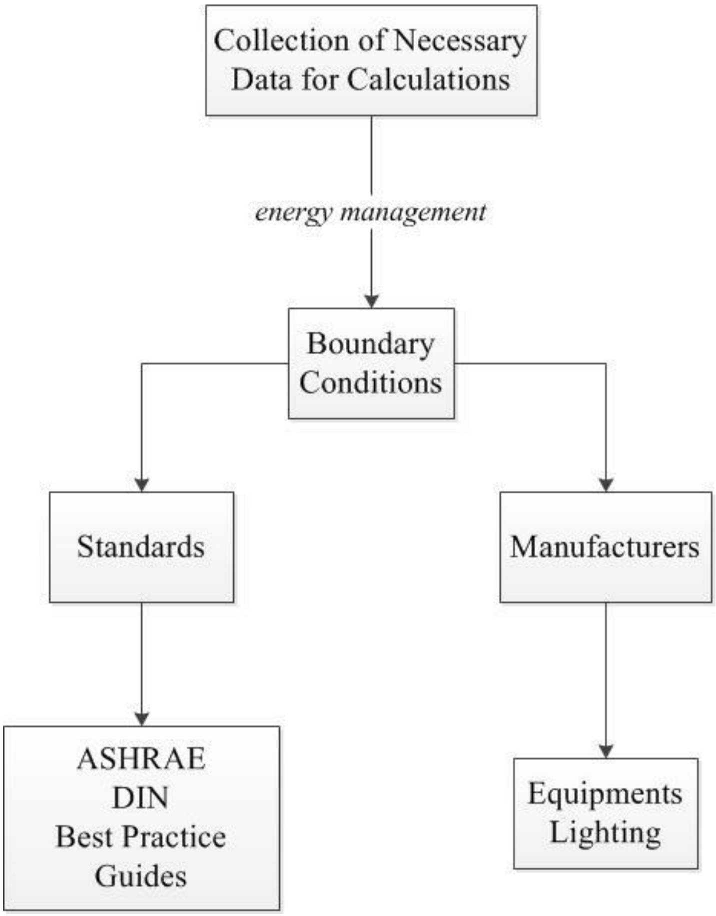


Figure 6.1 : Method to obtain data for hospital energy performance assessments

It is very important to have complete and accurate data for the energy performance assessments of hospital buildings. Useful standards for hospital input data should be decided for example by governments or researchers. Since it is easier to find general hospital input data these data should be determined, however it should be considered that some of the data, for example ventilation values, can differ according to the national standards.

After this, each country should have its own libraries for branch hospital input data. In this case, it could be possible and easier to assess realistic energy performance of hospital buildings.

Energy performance calculation of complex buildings and because of the even more complex typology of them energy performance calculation of hospital buildings is not a problem only in Turkey, it is a problem in all countries. Nowadays, internationally recognized dynamic simulation tools Energy Plus, TRNSYS, SPR are considered to be useful to calculate the energy performance of complex buildings in some European countries. However, these kind of tools require ability of energy modeling with dynamic methods and there is not a lot of people to be able to use that kind of tools. Even after an education for these tools, there will be a control problem on how the energy assessor uses the tool.

For this problem, two ways can be followed as required in Figure 6.2.

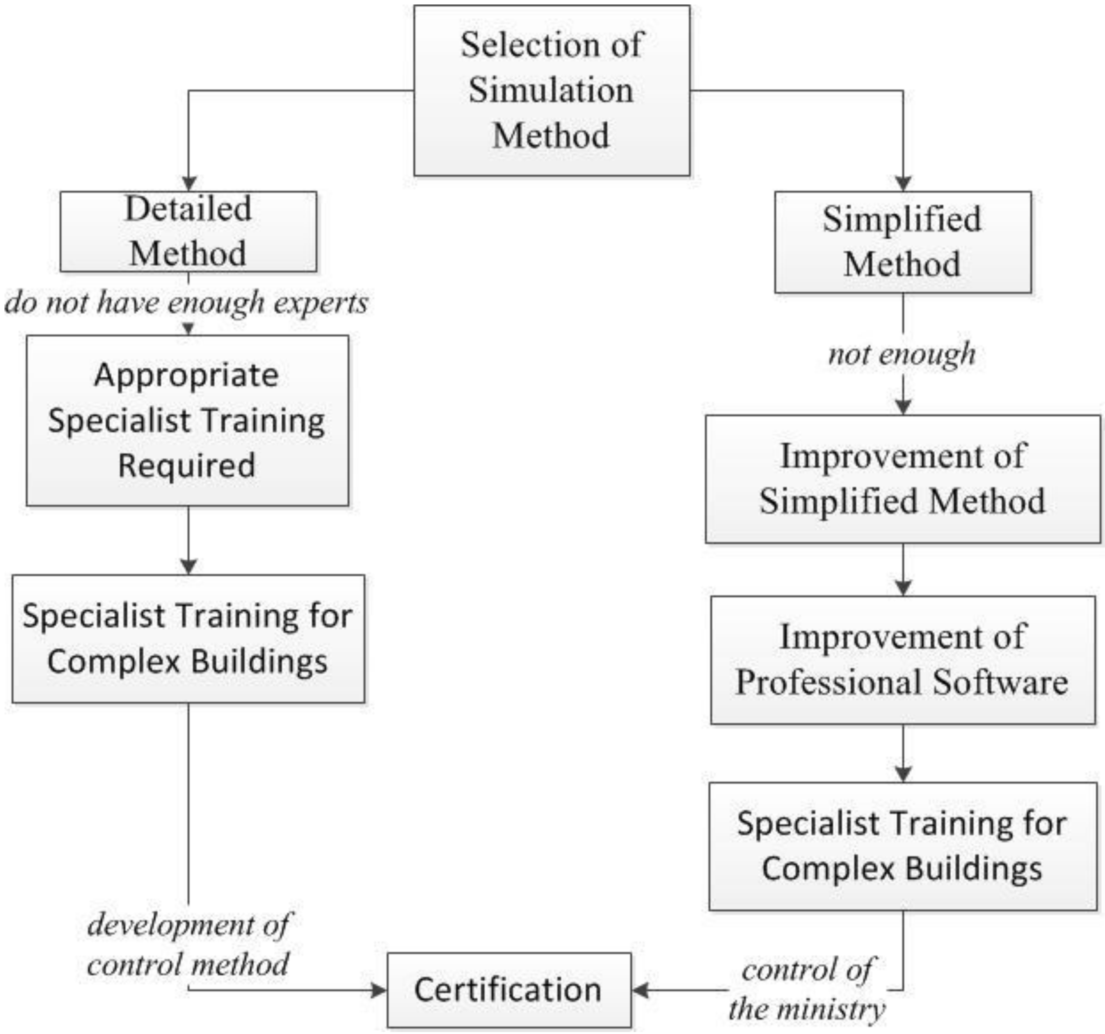


Figure 6.2 : Methods for complex building energy performance assessments

If the dynamic methods will be used for energy performance calculations of hospital buildings, there should be an extensive training program for the detailed dynamic simulation tools and a control method should be adopted to control the energy assessors for the usage of the method. If the simplified method will be used for energy performance calculations of hospital buildings, the simplified method should be improved to be able to assess energy performance of complex buildings and the professional software for simplified method should also be improved. Then, assessors should be trained for this improved method. It is the aim of this thesis to show in which points the simplified method can be improved to be able to assess the energy performance of hospital buildings. Therefore, the analysis of this thesis and other similar researches can be used to improve simplified method.

Therefore, if assessments are done by detailed method, there should be a control method for the assessors to check usage of the tool. However, if assessments are done by simplified method, ministries or associations related to energy performance simulations of buildings can control the usage of the method and, also assessors.

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